

UNCLASSIFIED

Space Surveillance Network (SSN) Optical Augmentation (SOA)

AFTER INITIATIVE REPORT APPENDIX



DISTRIBUTION STATEMENT A
Approved for Public Release
Distribution Unlimited

Kenney Class Initiative

**Air Force Space Battlelab
730 Irwin Ave, Ste 83
Schriever AFB CO 80912-7383**

April 1999

UNCLASSIFIED

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) xx-04-1999		2. REPORT TYPE Technical Publication (Report)		3. DATES COVERED (From - To) 11-09-1999 to 01-04-1999	
4. TITLE AND SUBTITLE Space Surveillance Network (SSN) Optical Augmentation (SOA) Append. x				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Andress, Walter ; Author				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Space Battlelab 730 Irwin Ave, Ste 83 Schriever AFB, CO 80912-7383				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Space Battlelab 730 Irwin Ave, Ste 83 Schriever AFB, CO 80912-7383				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT A Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT This report contains detailed textual and graphical data obtained during the SOA initiative.					
20000103 074					
15. SUBJECT TERMS Space Surveillance, Deep Space, Optical Telescopes, Space Surveillance Network (SSN), Satellite Tracking					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same As Report	18. NUMBER OF PAGES 49	19a. NAME OF RESPONSIBLE PERSON MSgt Joel Stolzmann
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED			19b. TELEPHONE NUMBER (include area code) 719-567-9992

1. Nightly Mission Analysis

The following sections detail the performance condition for each night during pretest and test phase and provide insight into the effects of hardware configuration, autonomous operations, SOA-ODSP communications, lunar sky background, and weather. The pretest phase operations on Days 191, 195, 196, and 199 are included to provide a larger range of lunar sky background, weather, and hardware conditions. Summary tables are included with statistics computed on an hourly basis.

A. Day 191 (10 Jul 98 UT)

Operating Environment

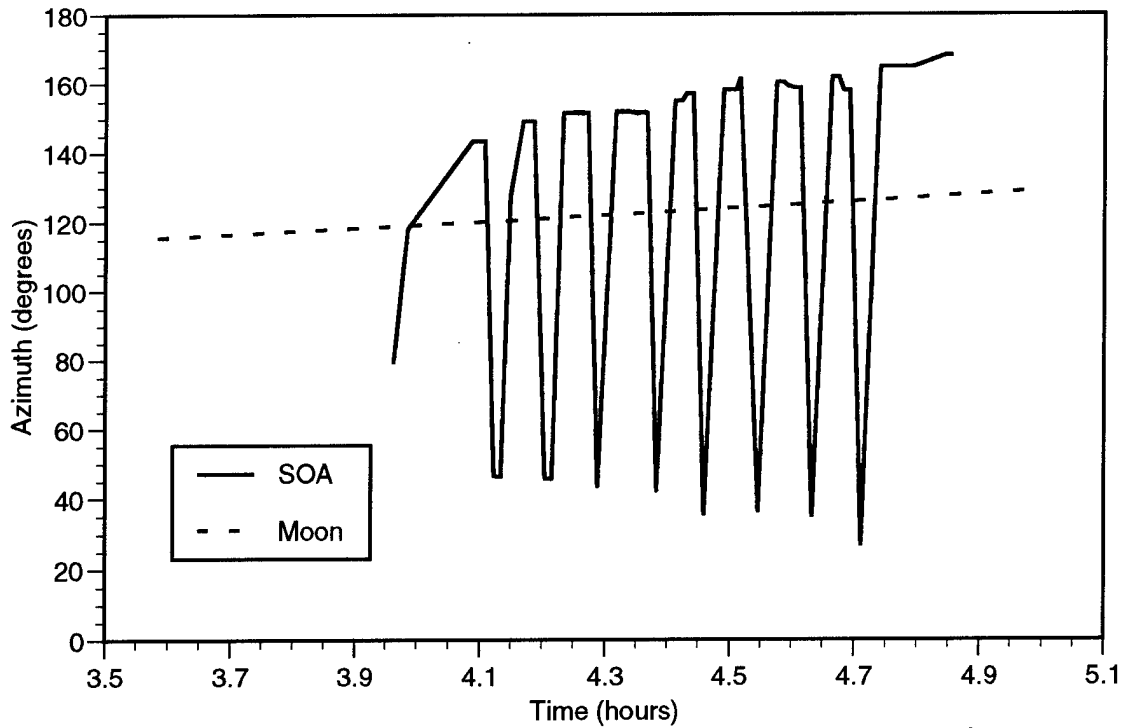
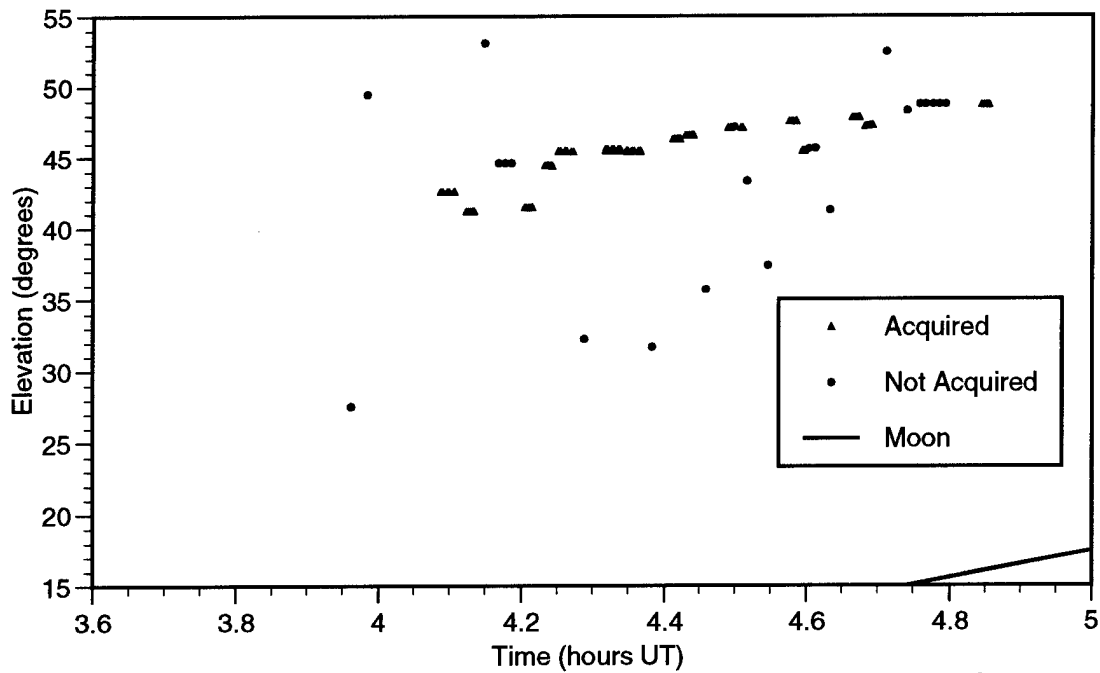
Weather: Green
 Lunar Background: Moon max elevation: 17° Illumination: 100%
 Hardware Condition: Some image defocus

The data collection on 10 Jul 98 was terminated shortly after operations began due to concerns of telescope focus and only a single hour of data was collected. Although the sample set is small, the analysis does reaffirm the trends seen in other test dates and hints to the affects of image defocus on catalog star matching. As evident in Figure 1, all the tasked objects were on the eastern half of the sky and did not cross the meridian, resulting in an attempt/hour rate of 38. This figure also shows that ODSP scheduler is trying to schedule about the moon position. Although the moon was full, it was low in the sky and did not largely affect the acquisition. Figure 2 shows no acquisition of objects below 40° and closer to the moon. The defocus noted in the images reduced the number of guide stars matched, shown in Figure 3, by about 10%. Figure 4 shows a higher acquisition rate for objects with a lower phase and poor performance for objects whose phase angle is greater than 75°. Note: a lower phase angle means more direct illumination by the sun as seen by the observer.

Legend			
Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
191	0.8	31	0	2	11	3	15	4	38

Table 1 Observation summary for Day 191 (10 Jul 98 UT)

**Figure 1 Azimuth Positions for Day 191 (10 Jul 98 UT)****Figure 2 Elevation Positions for Day 191 (10 Jul 98 UT)**

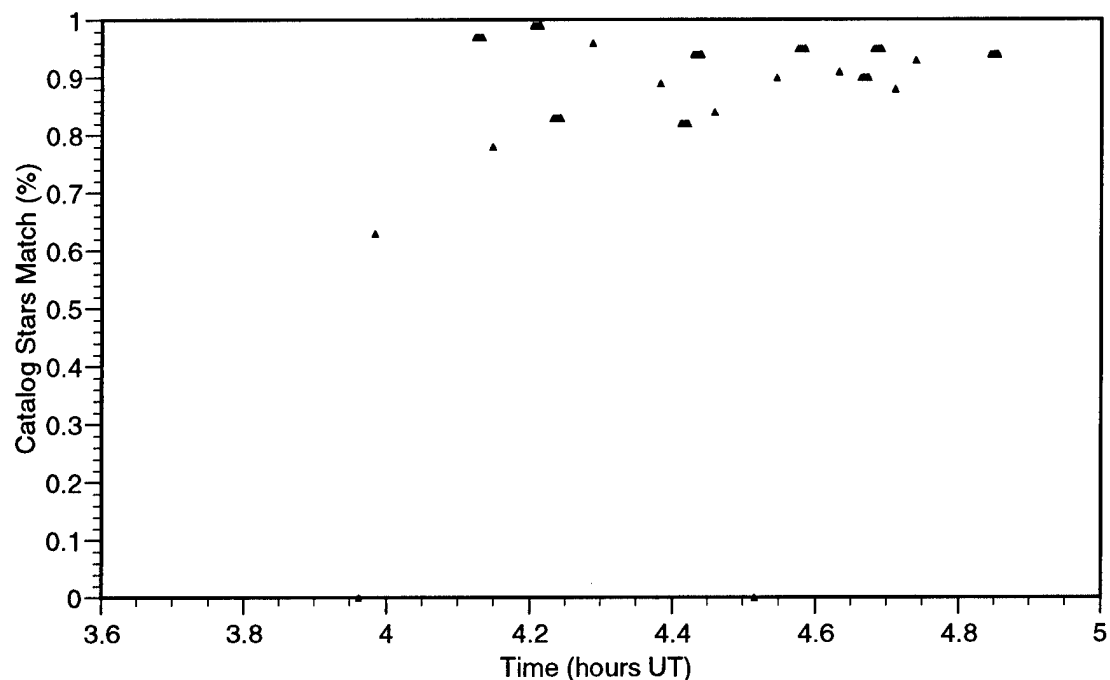


Figure 3 Catalog Star Match Percentage for Day 191 (10 Jul 98 UT)

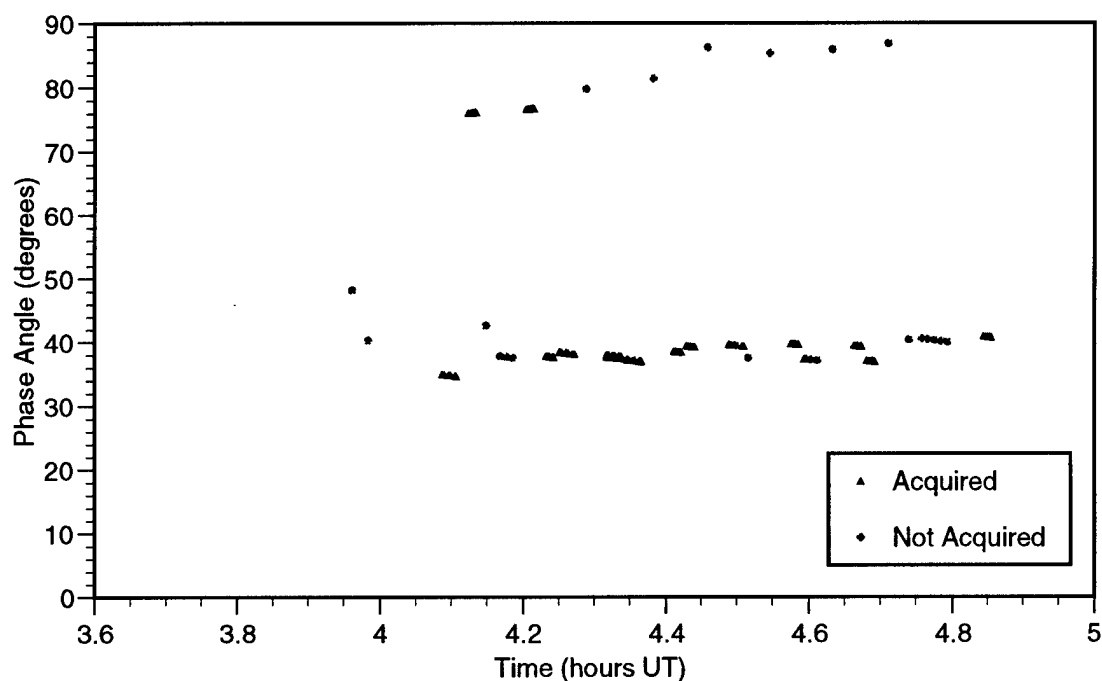


Figure 4 Satellite Phase Angles for Day 196 (10 Jul 98 UT)

B. Day 195 (14 Jul 98 UT)

Operating Environment

Weather: Green

Lunar Background: Moon max elevation: 50° Illumination: 76%

Hardware Condition: Increasing image defocus

AFRL delayed startup of the system for four hours, as poor focus was apparent in the images collected at the start of the night. An effect of the defocus and lunar sky background can be seen in Figure 7 where star match percentage varied from 50% to 90%, and 21 images did not have sufficient catalog star detection for the star pattern match to converge. By comparing with Figure 6, we see that as the moon rose in elevation, the star match percentage dropped. Accordingly, the satellite acquisition rate was high at the start of the night, but fell as the moon rose.

Two factors contribute to the effect of lunar sky background on the SOA images. First, the SOA telescope is an open truss to reduce weight, but it does little to hinder the lunar light reflections. Second, the interior dome wall is bare aluminum that has reasonable reflective characteristics. During system integration, we added a crude baffle to the camera aperture. However, with the low signal to noise of the defocused images, the scattered lunar light tends to overwhelm dim stars. The image defocus was a major concern during this phase of testing, since there was no autonomous mechanism to set "best" focus. The environmental temperature fluctuation was a suspected cause of the optical focus change.

There were some breaks in operations in the first and last hours of the night, but during the second hour, 0730 to 0830 UT, operations were uninterrupted, but the number of attempts (#Att) was on 30/house, while between 0830 to 1030 UT, the throughput was 40 attempts/hour and 45 attempts/hour, respectively. If we examine the azimuth position plot, Figure 5, there are 14 meridian crossings. These motions require a complete rotation of the mount and add 30 seconds or more to the telescope slewing time. Figure 8 shows that all tasked objects had nearly optimal phase angle. The importance of the analysis is on Day 195 is that image defocus can result in a reduction of catalog stars matched.

Legend

Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
195	1	6	0	0	2	2	2	0	N/A
195	1	29	1	5	5	5	13	2	N/A
195	1	40	0	5	16	6	11	3	N/A
195	1	45	0	6	15	3	21	3	N/A
195	0.7	27	0	5	16	2	4	2	N/A
Total	4.6	147	1	21	54	18	51	10	32

Table 2 Observation summary for Day 195 (14 Jul 98)

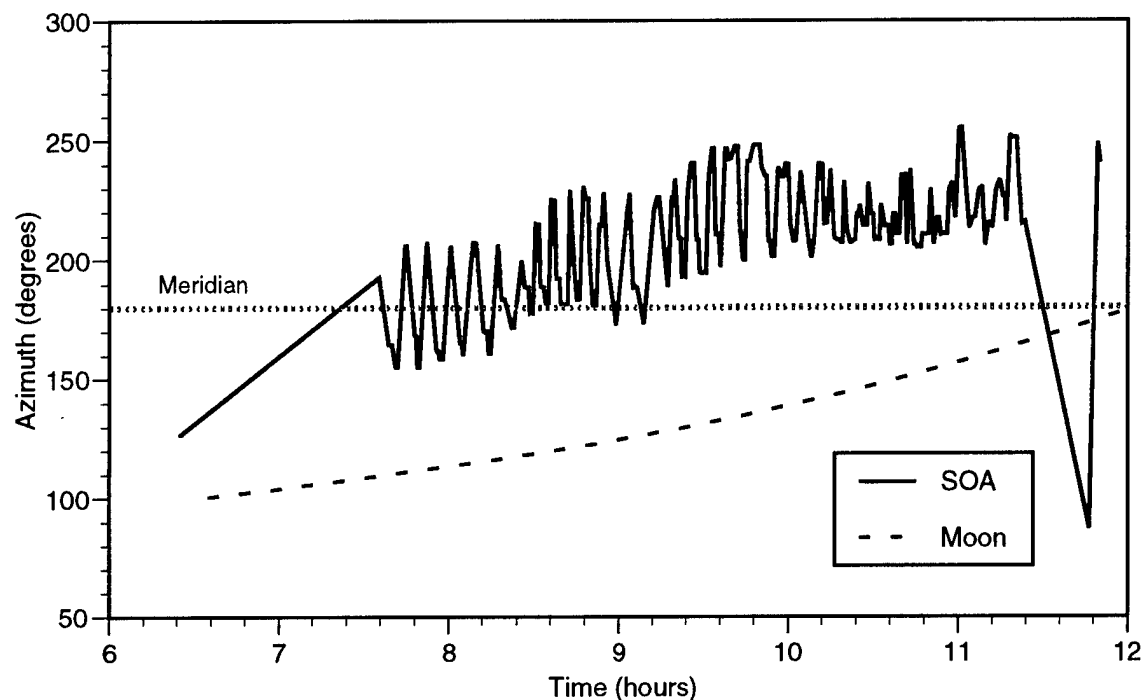


Figure 5 Azimuth Positions for Day 195 (14 Jul 98 UT)

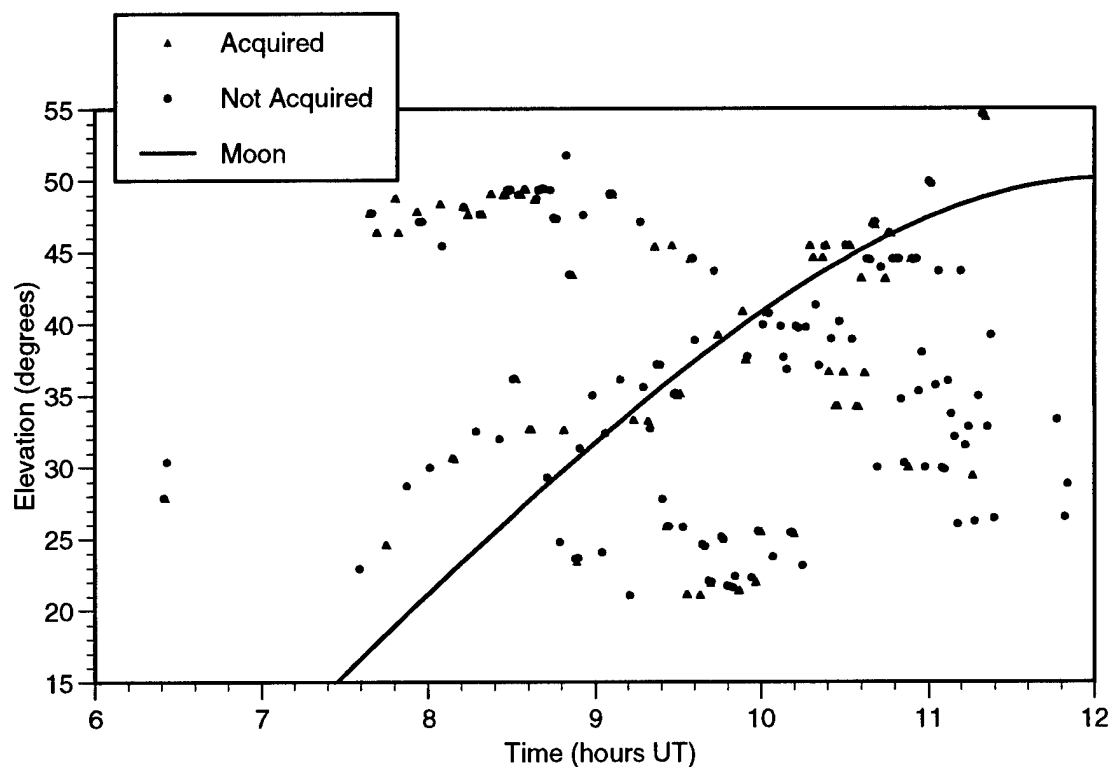


Figure 6 Elevation Positions for Day 195 (14 Jul 98 UT)

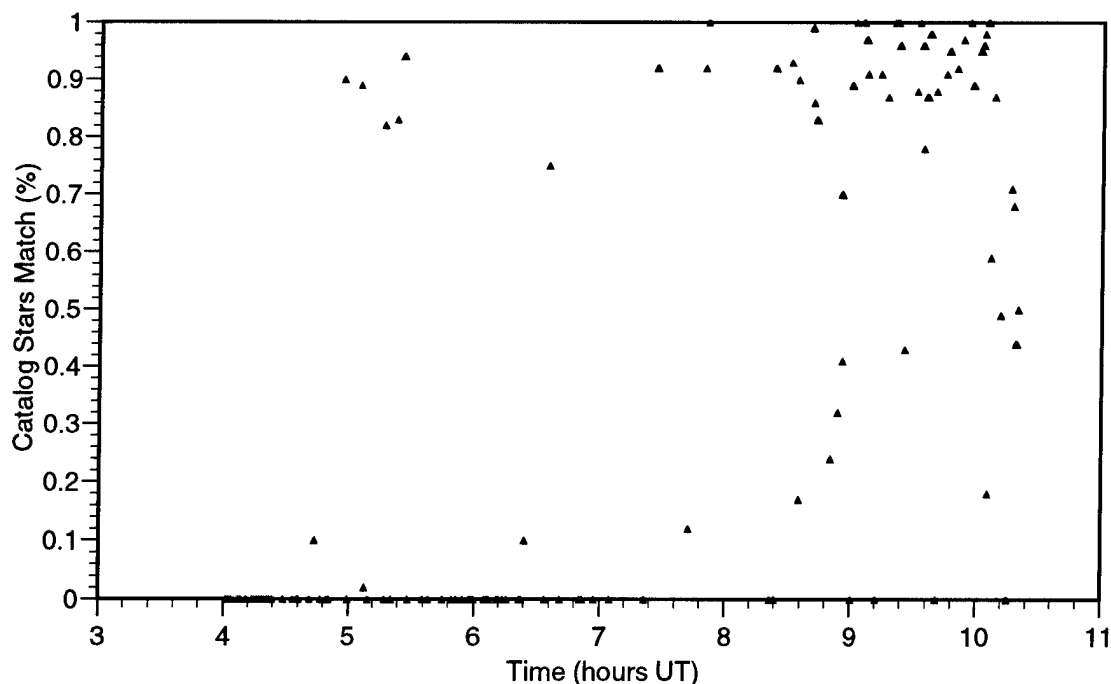


Figure 7 Catalog Star Match Percentage for Day 195 (14 Jul 98 UT)

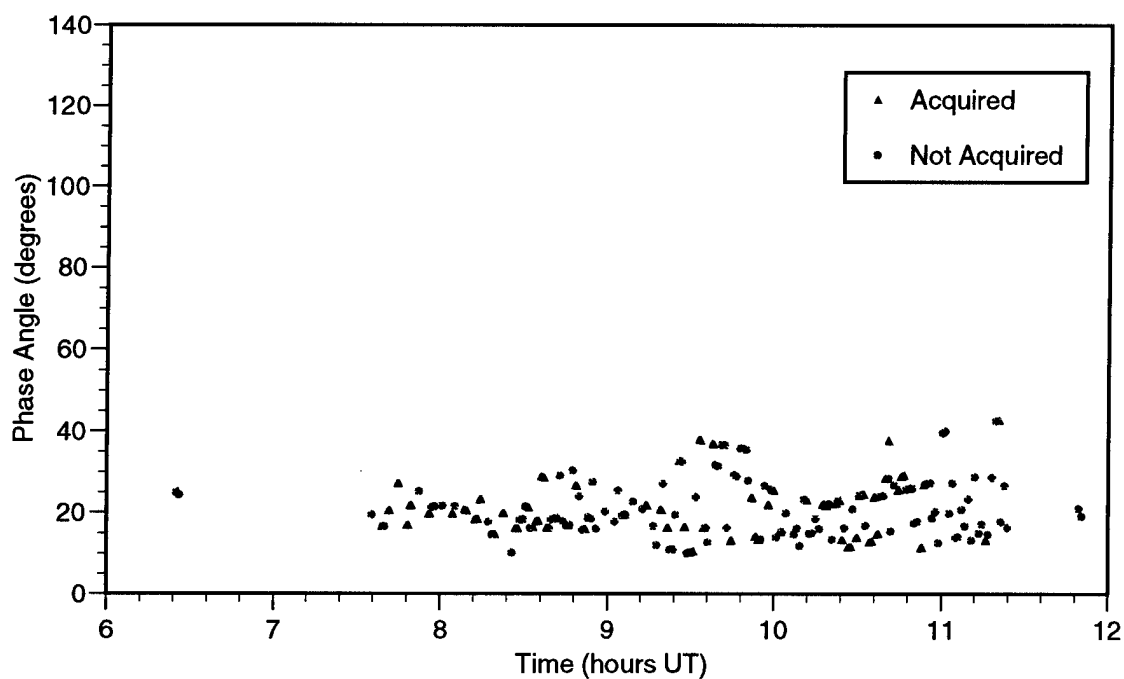


Figure 8 Satellite Phase Angles for Day 195 (14 Jul 98 UT)

C. Day 196 (15 Jul 98 UT)

Operating Environment

Weather: Green

Lunar Background: Moon max elevation: 52° Illumination: 66%

Hardware Condition: Increasing image defocus, system troubleshooting between 05 and 08 hours UT.

Similar to 14 Jul 98, the data collection on 15 Jul 98 was terminated shortly after operations began due to concerns of telescope focus and only four hours of data was collected at the end of the night. The focus appeared to degrade even further from the previous night. Space Battlelab personnel were at Edwards to help troubleshoot the focus problem. It was determined that the focus changes seen over the previous nights were due to focus adjustment set screws not remaining tight. The focus changes seen were not due to thermal variations. The analysis of Day 196 is also akin to Day 195. The catalog star match percent in Figure 11 varied between 10% and 90% with 26 'U' miscodes where catalog star match did not converge. The catalog match reduction correlated well with the rising moon shown in Figure 10. Reduced throughput due to meridian crossing is evident between 09 and 10 hours UT going from 40 to 48 attempts / hour down to 30 attempts / hour. Surprisingly, object acquisition success rate reduced greatly in the last 1.3 hours.

Legend

Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
196	0.6	21	0	2	8	4	6	0	N/A
196	1	39	3	8	11	3	16	5	N/A
196	1	30	4	4	11	1	14	1	N/A
196	1	48	0	10	25	1	12	1	N/A
196	0.3	18	1	2	15	0	1	1	N/A
Total	3.9	156	8	26	70	9	49	8	40

Table 3 Observation summary for Day 196 (15 Jul 98)

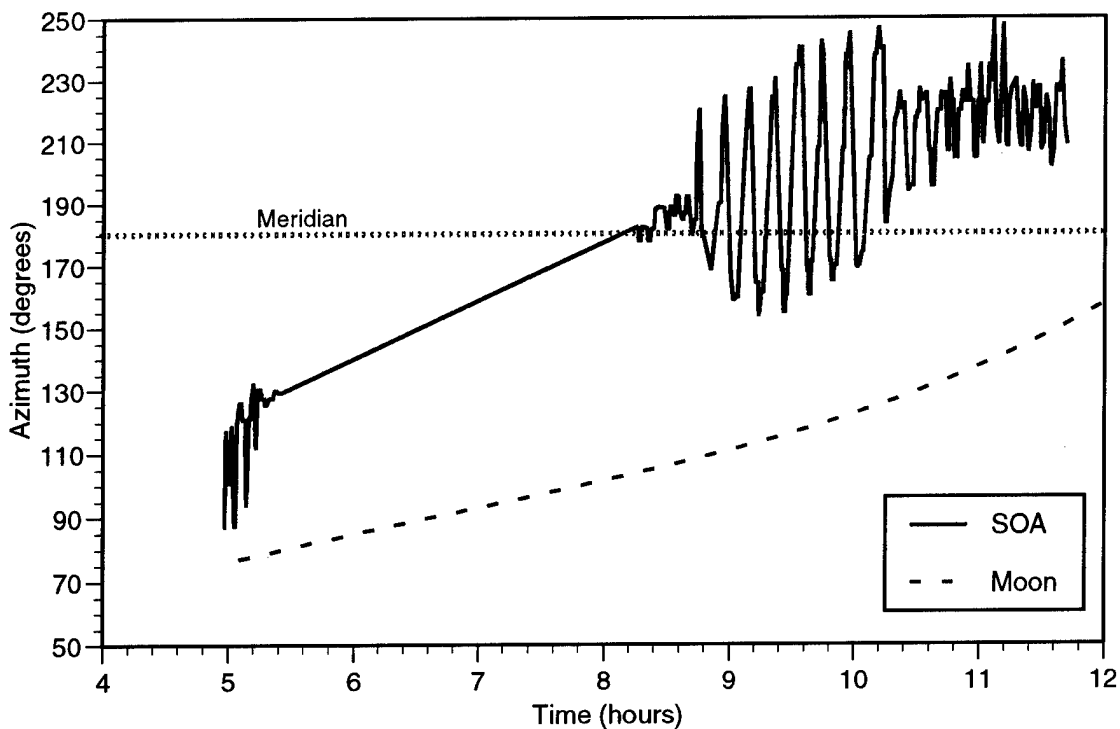


Figure 9 Azimuth Positions for Day 196 (15 Jul 98 UT)

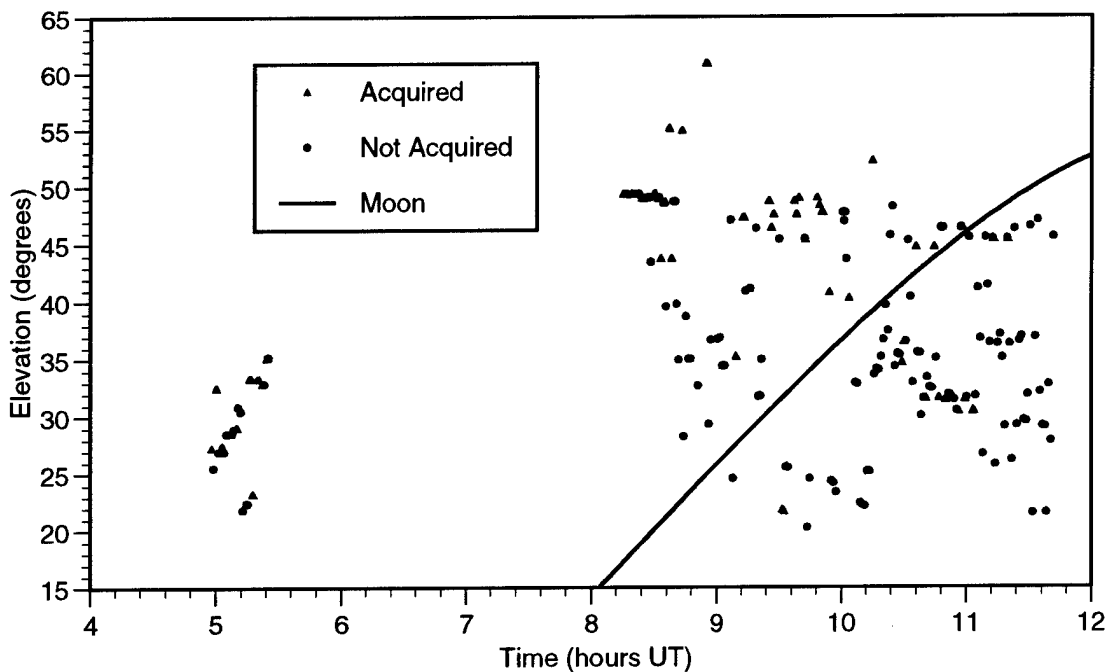


Figure 10 Elevation Positions for Day 196 (15 Jul 98 UT)

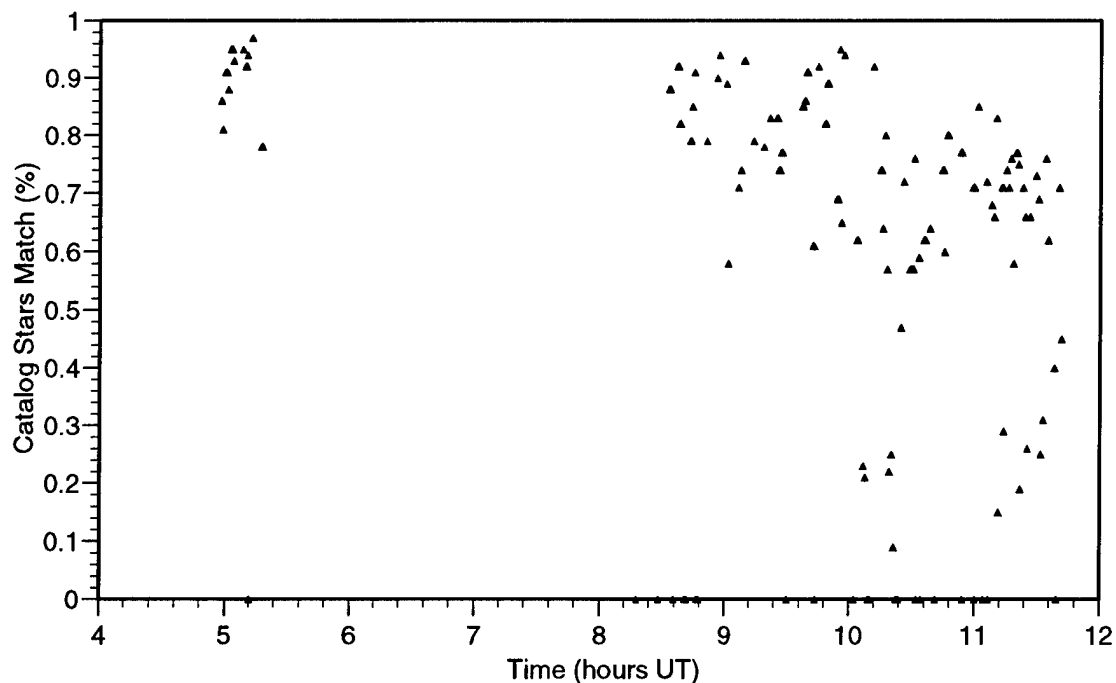


Figure 11 Catalog Star Match Percentage for Day 196 (15 Jul 98 UT)

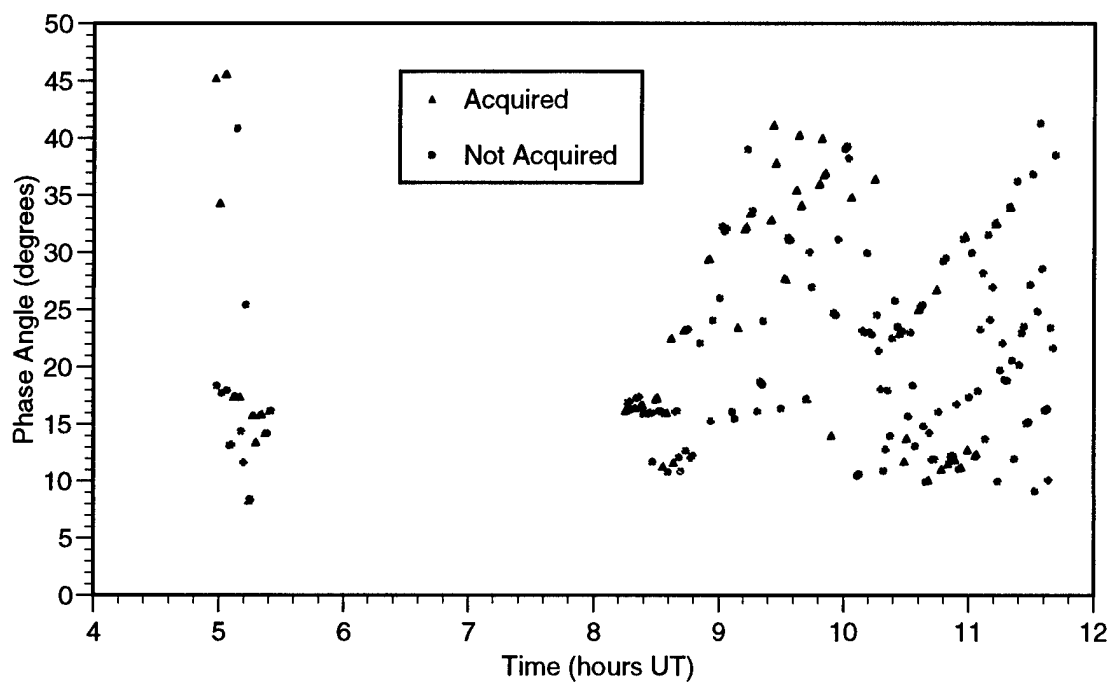


Figure 12 Satellite Phase Angles for Day 196 (15 Jul 98 UT)

D. Day 199 (18 Jul 98 UT)

Operating Environment

Weather: Green

Lunar Background: Moon max elevation: 13° Illumination: 30%

Hardware Condition: Mount Imbalance

The SOA telescope was properly focused on 17 Jul 98 UT, but due to some configuration changes on 15 Jul 98, the mount was unbalanced and stuck in a fixed position several times during the night's operations. The improved focus is apparent by examining Figure 15, where catalog star match percentages average near 90% or above. Satellite acquisition rate was high during the first three hours of testing. Throughput is difficult to evaluate for this night, since the mount was periodically sticking, causing large gaps in observations and evident in all the plots. After four hours, the Space Battlelab stopped operations and testing discontinued until AFRL could properly balance the mount. An important conclusion to draw from these pretest days is that image defocus can reduce the catalog star match rate as well as the acquisition rate, particularly in the presence of lunar sky background.

Legend			
Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
199	1	30	0	4	9	2	15	4	N/A
199	0.9	29	0	4	2	2	21	10	N/A
199	0.9	32	0	3	7	4	18	0	N/A
199	0.4	10	0	1	4	3	2	0	N/A
199	0.06	4	0	0	0	0	4	0	N/A
Total	3.3	105	0	12	22	11	60	14	32

Table 4 Observation summary for Day 195 (14 Jul 98)

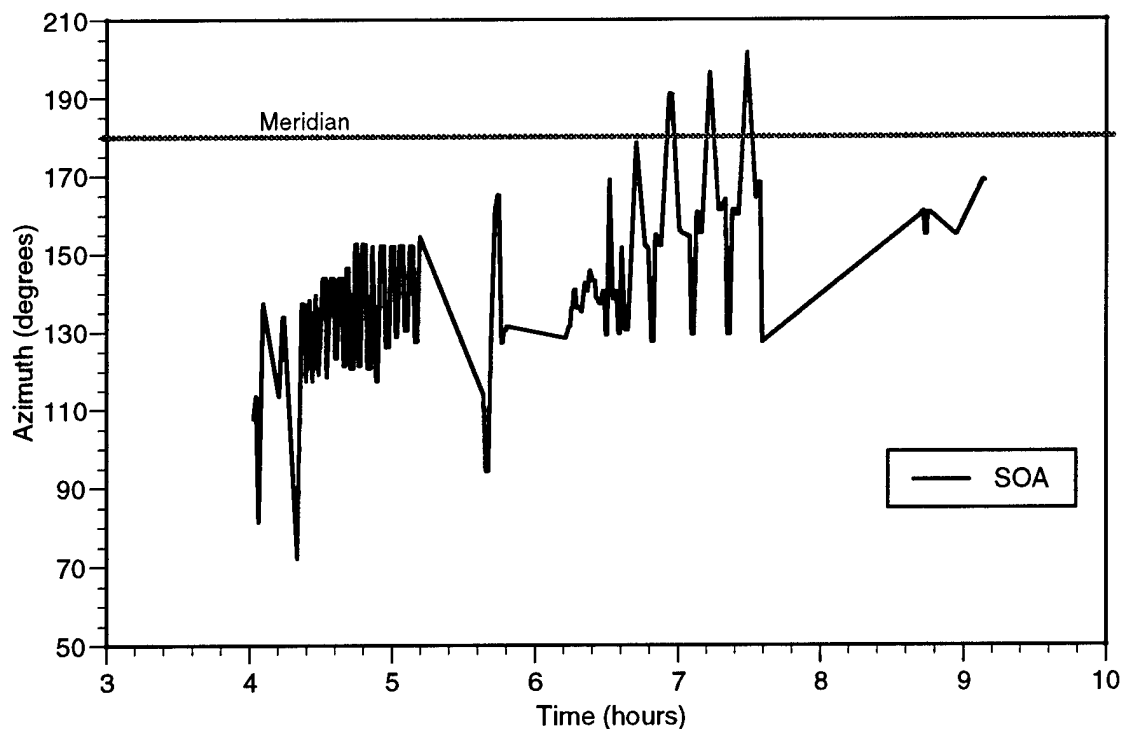


Figure 13 Azimuth Positions for Day 199 (18 Jul 98 UT)

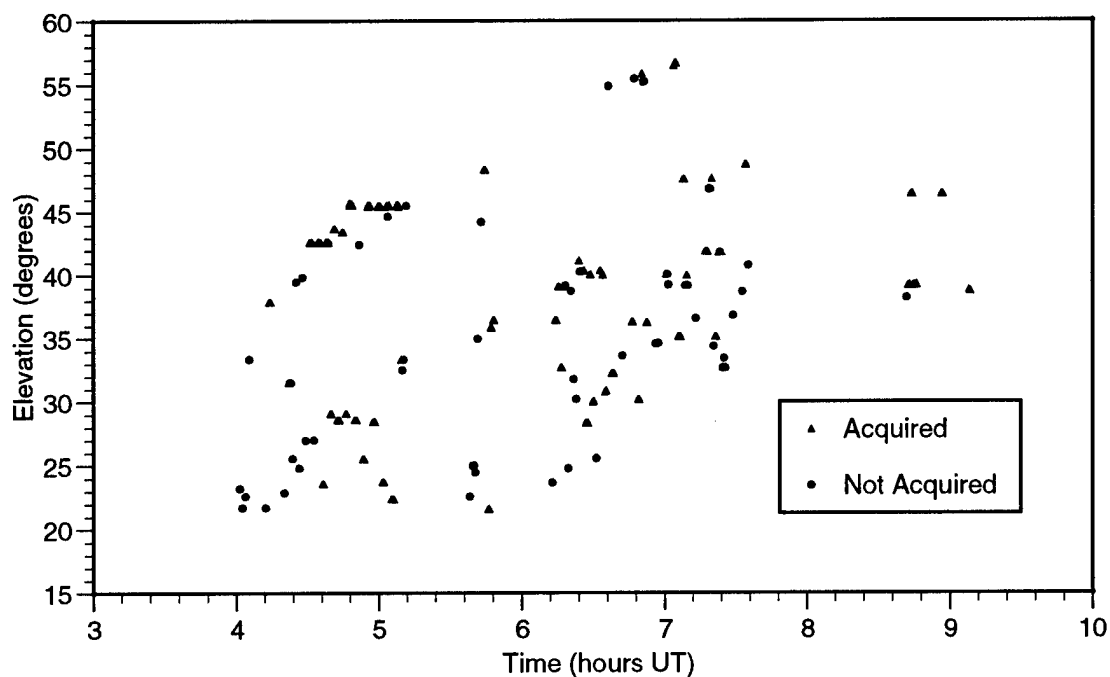


Figure 14 Elevation Positions for Day 199 (18 Jul 98 UT)

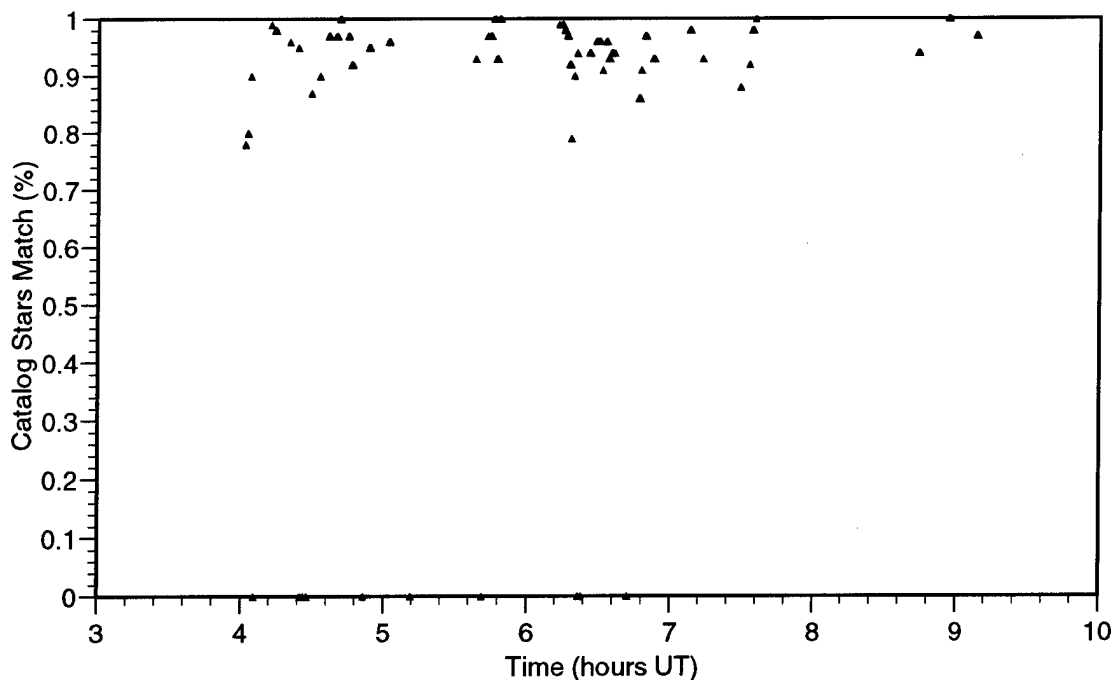


Figure 15 Catalog Star Match Percentage for Day 199 (18 Jul 98 UT)

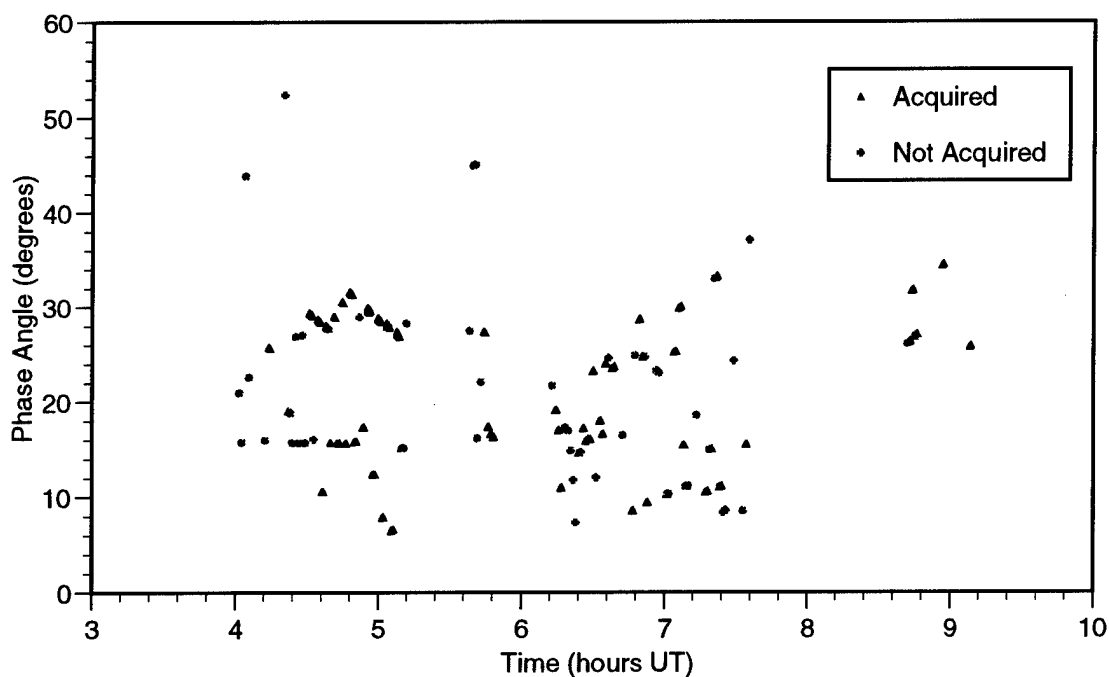


Figure 16 Satellite Phase Angles for Day 199 (18 Jul 98 UT)

E. Day 209 (28 Jul 98 UT)

Operating Environment

Weather: Green
Lunar Background: Below horizon

Hardware Condition: Normal

Day 209 was the first day of the autonomous test period. AFRL had rebalanced the mount and adjusted the focus to a good setting. AFRL fixed the focus adjustment screws in place and the image focus remained acceptable through the remainder of the 18-day test period. The Telescope Control PC appeared to be inoperative at the start of operations around 0350 UT and may be attributed to the memory leak, but without remote monitoring capability, it is difficult for SOA personnel in Maui to troubleshoot. Therefore, OC³F personnel on-site at Edwards were required to restart the Telescope Control PC.

Because of the four-hour system startup delay, the fixed telescope pointing position reported, resulted in the anomalous tasking. The throughput and acquisition rate was low in the first hour of operations between 0830 and 0930 hours UT. As evidenced from Figure 17, there were numerous meridian crossings, which due to the nature of the SOA German Equatorial mount, reduced the throughput. One might attribute low acquisition rate during this first hour to a combination of low elevation (Figure 18) and high phase angle (Figure 20). The weather appears clear as inferred from the high percentage of catalog star matching in Figure 19. After this first hour, the tasking "settled out" and a throughput of more than 50 tracks per hour and improved acquisition rate is apparent. In the last hour, the throughput suffered from meridian crossing effects.

Legend

Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
209	0.04	5	0	0	2	1	2	0	N/A
209	1	28	1	8	8	0	9	2	N/A
209	1	55	0	6	7	13	29	20	N/A
209	0.9	54	1	4	5	9	33	22	N/A
209	0.4	14	2	0	3	2	9	3	N/A
Total	3.4	156	4	18	25	25	82	47	46

Table 5 Observation summary for Day 209 (28 Jul 98)

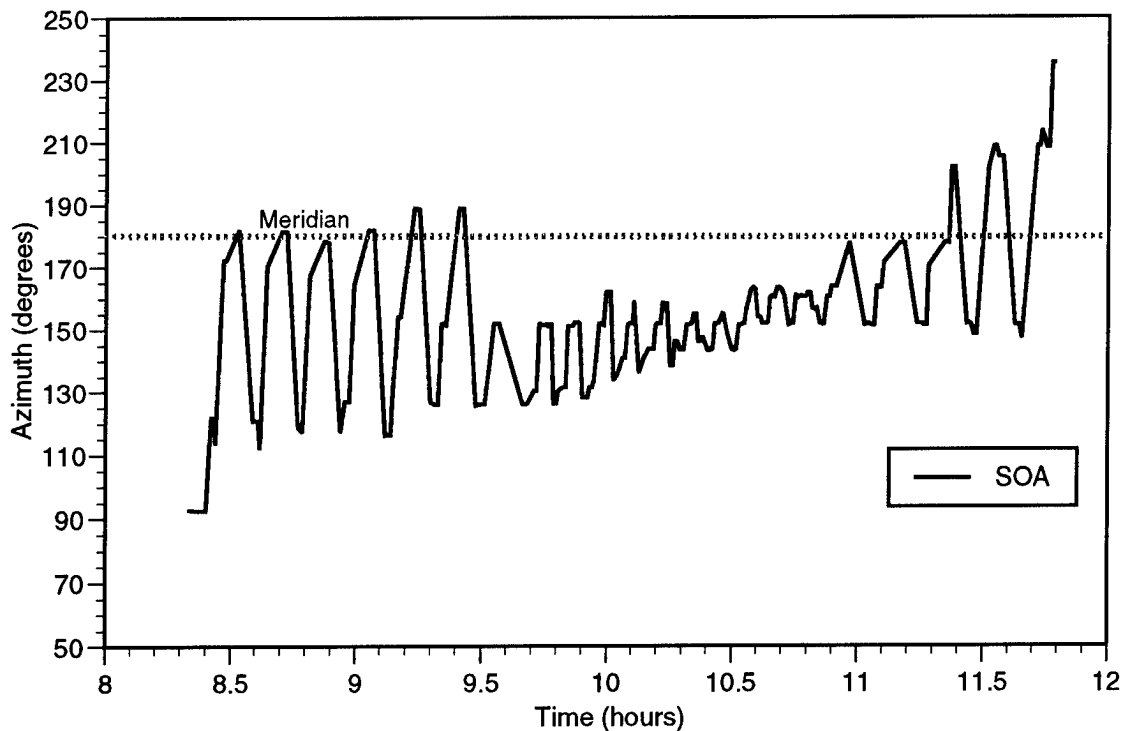


Figure 17 Azimuth Positions for Day 209 (28 Jul 98 UT)

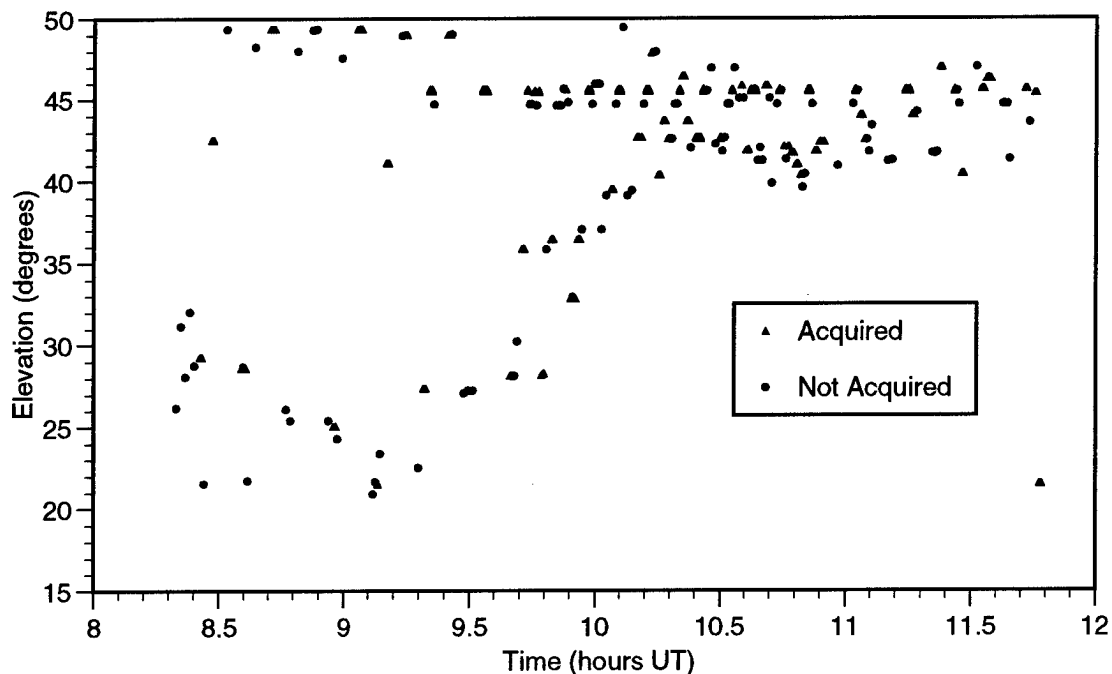


Figure 18 Elevation Positions for Day 209 (28 Jul 98 UT)

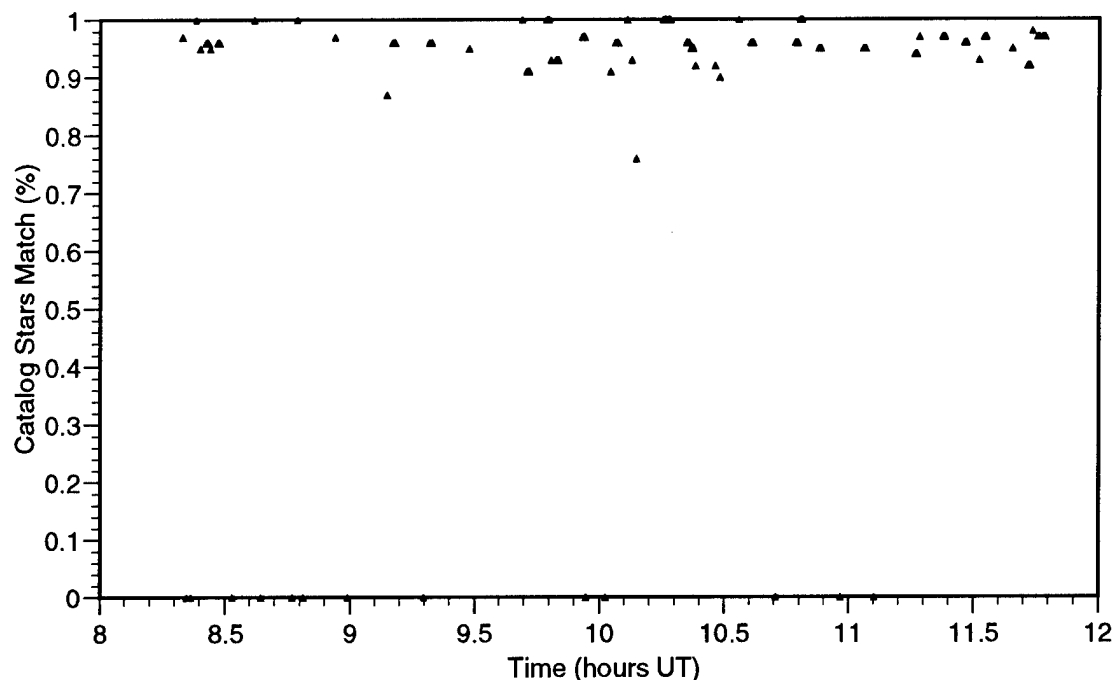


Figure 19 Catalog Star Match Percentage for Day 209 (28 Jul 98 UT)

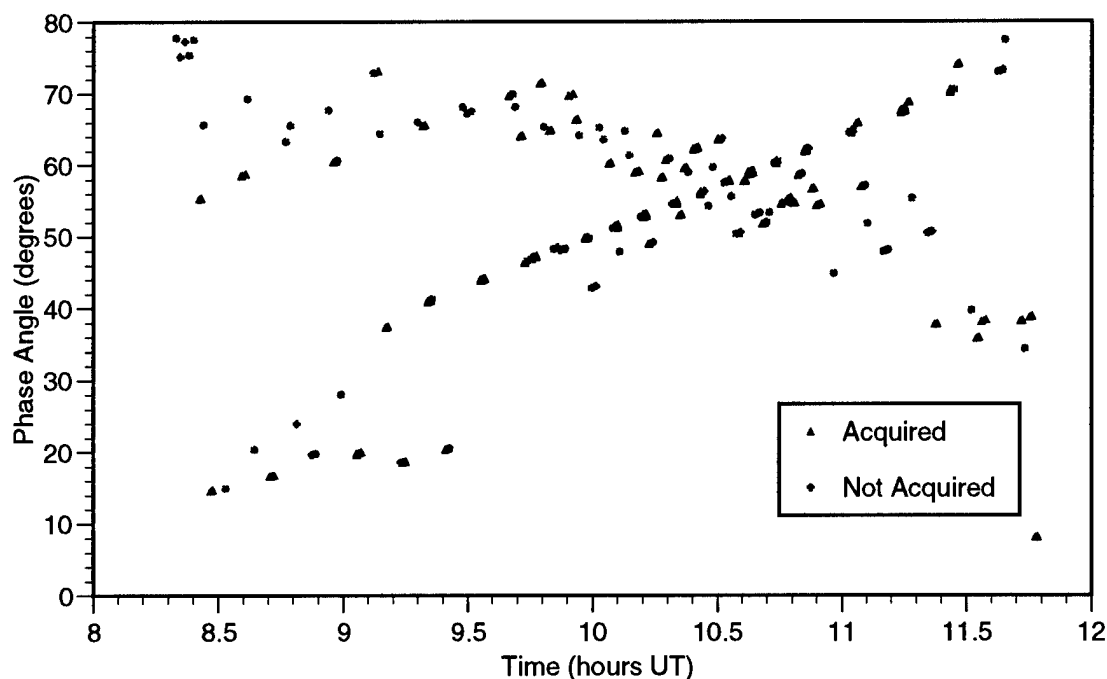


Figure 20 Satellite Phase Angles for Day 209 (28 Jul 98 UT)

F. Day 210 (29 Jul 98 UT)

Operating Environment

Weather: Green
Lunar Background: Moon max elevation: 35° Illumination: 30%

Hardware Condition: Normal

Table 6 shows high throughput in the first 3 hours of operations, along with Figure 21, which shows steady motion on the eastern side of the meridian, minimizing mount motion. One may attribute a low acquisition rate in the first hour to the low elevation of observation coupled with a proximity to the moon in elevation. The phase angle of satellite solar illumination (Figure 24) is good through most of the night, except after restarting of the telescope control PC at the four-hour point (0740 UT). The fixed telescope starting angle causes an oscillation in tasking about the meridian illustrated in Figure 21 and Figure 22 as well as a subset of tasked objects at poor phase angle. ODSP tasked SOA a satellite, whose elset age exceeded 45 days, at 10:27:08, 10:38:04, and 11:19:08, which causes a scripting error in the telescope control computer. This causes a timeout of the Odin watchdog timer and idles the SOA system for more than 30 minutes. The percentage of matched catalog stars (Figure 23) consistently above 90% indicates clear skies throughout the night.

Legend			
Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
210	1	46	0	10	11	6	12	0	N/A
210	1	52	0	7	9	5	24	8	N/A
210	1	48	0	3	14	8	22	9	N/A
210	0.8	20	2	3	5	5	7	1	N/A
210	1	29	0	0	12	2	14	4	N/A
210	1	39	0	2	10	4	24	3	N/A
210	1	24	1	0	11	1	12	0	N/A
210	0.8	19	0	1	10	0	8	3	N/A
Total	7.5	277	3	26	82	31	123	28	37

Table 6 Observation summary for Day 210 (29 Jul 98 UT)

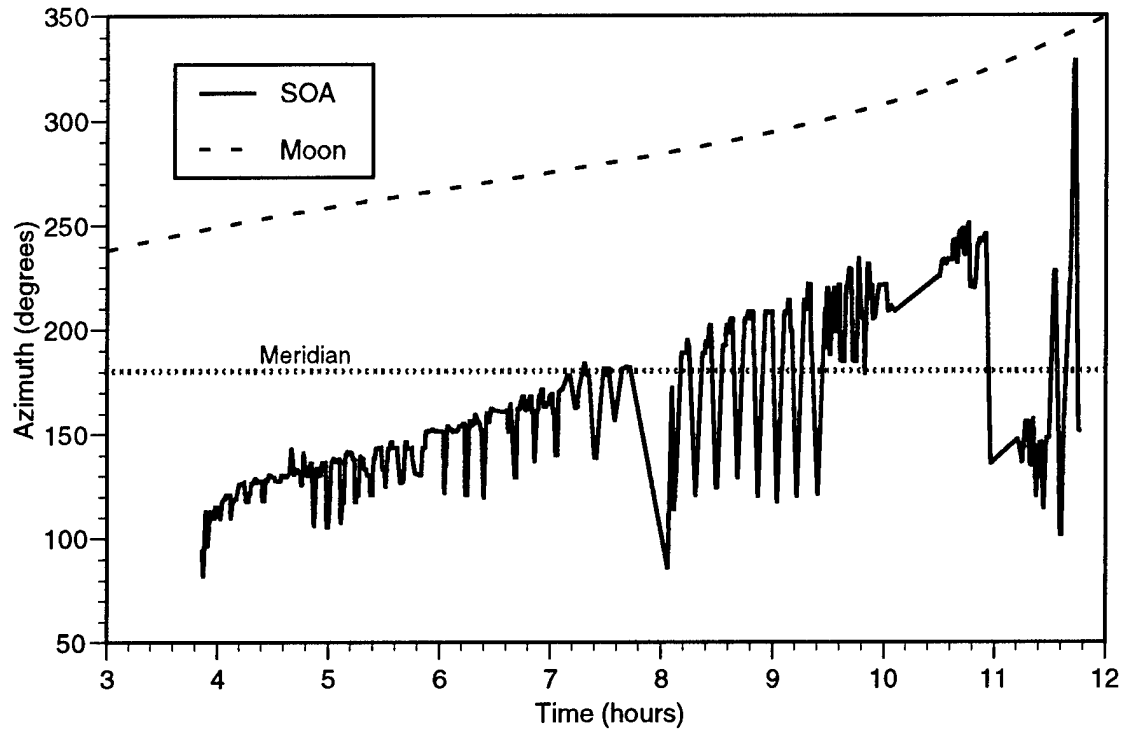


Figure 21 Azimuth Positions for Day 210 (29 Jul 98 UT)

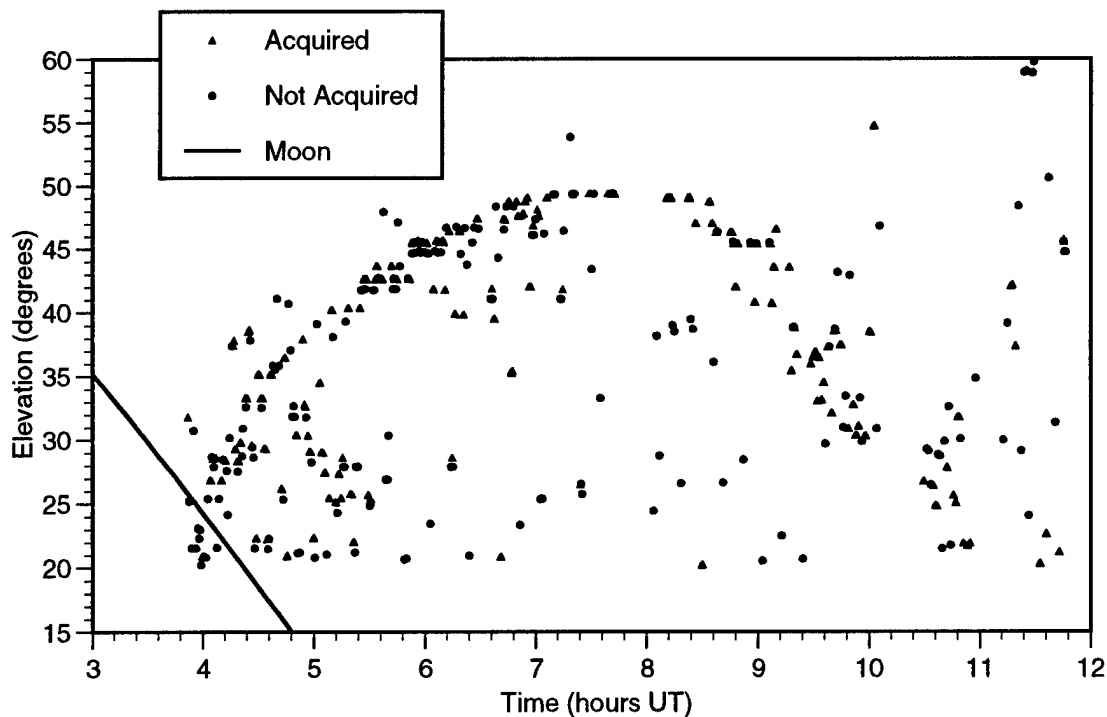


Figure 22 Elevation Positions for Day 210 (29 Jul 98 UT)

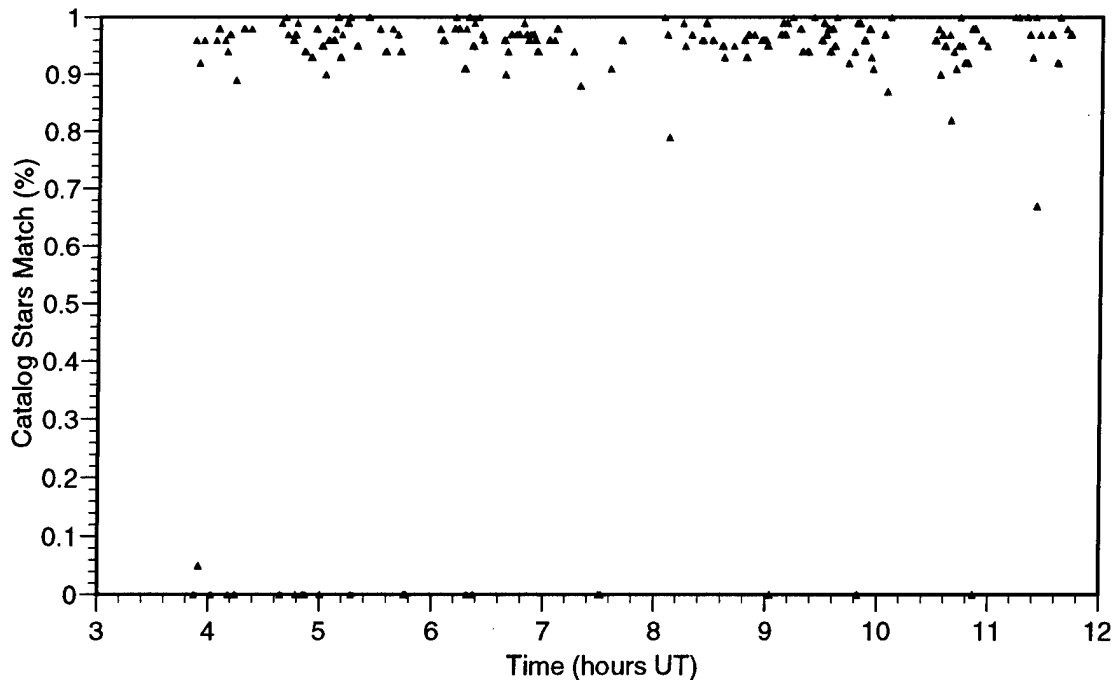


Figure 23 Catalog Star Match Percentage for Day 210 (29 Jul 98 UT)

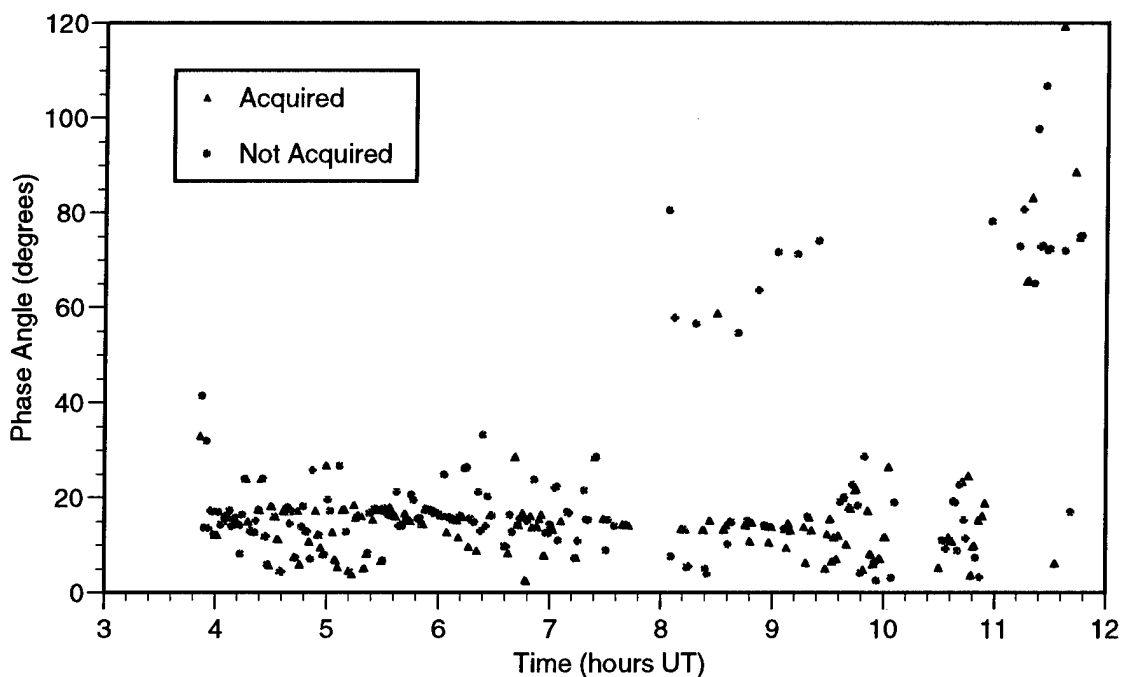


Figure 24 Satellite Phase Angles for Day 210 (29 Jul 98 UT)

G. Day 212 (31 Jul 98 UT)

Operating Environment

Weather: Green

Lunar Background: Moon max elevation: 40° Illumination: 47%

Hardware Condition: Normal

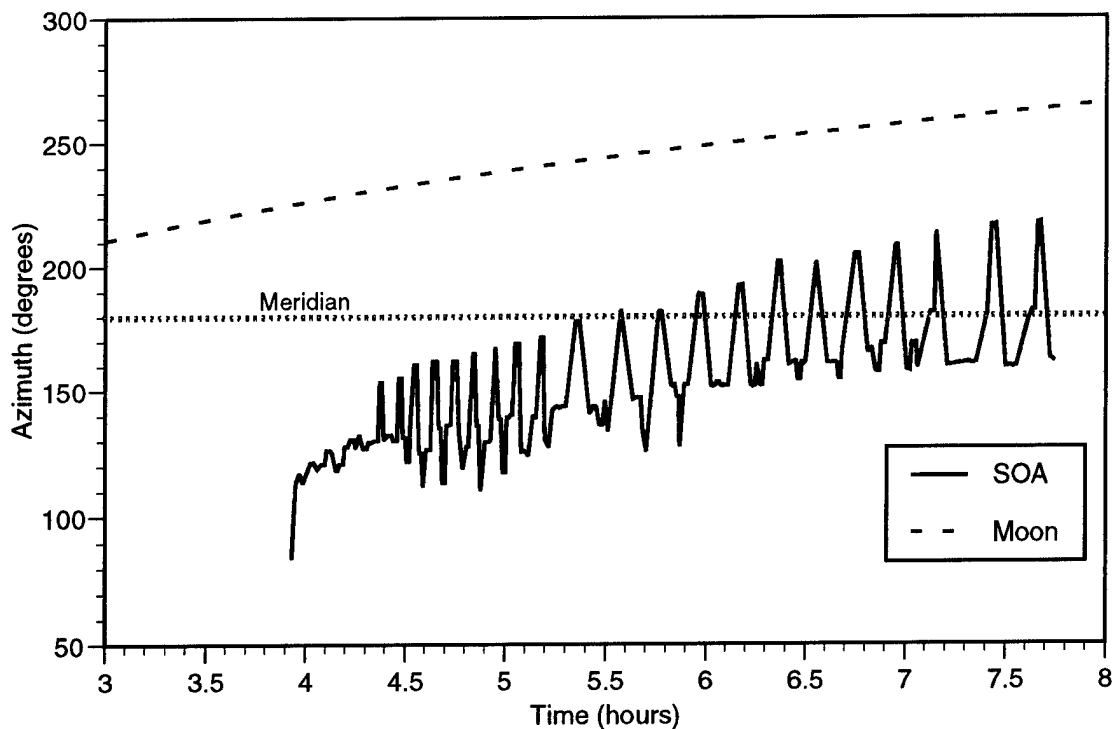
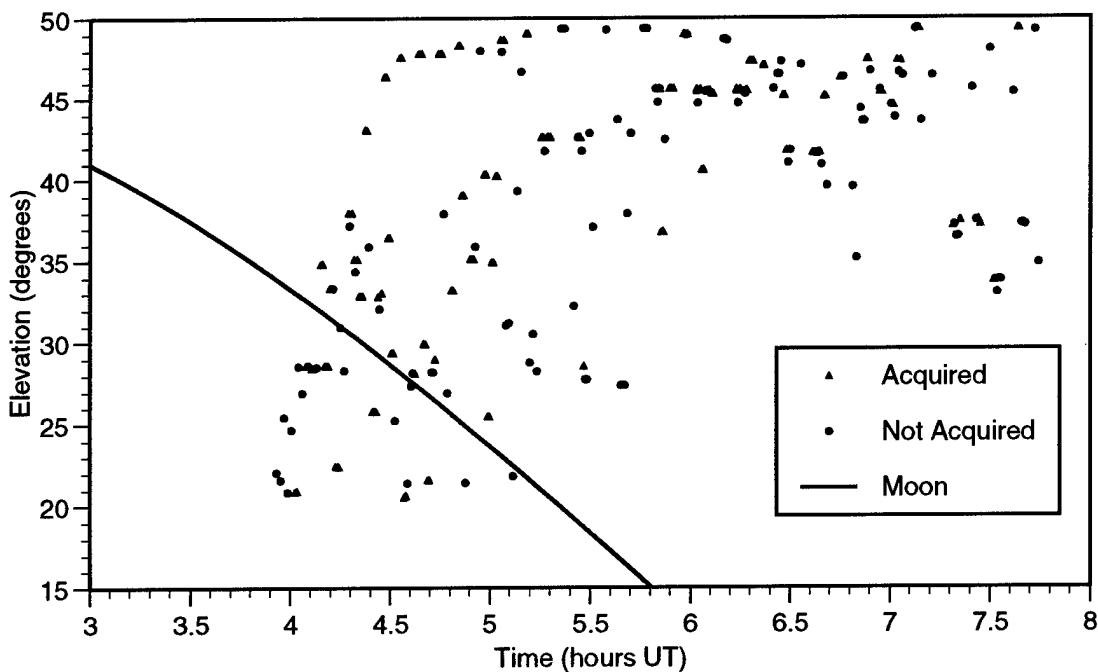
In the first hour of operations, the observation throughput is relatively high. However, as shown in Figure 25, increasing meridian crossing between 0530 and 0800 hours UT reduces the SOA throughput. Over the four hours of operation, 17 tracks resulted in a 'U' miscode. These miscodes may be attributed to close proximity of the moon for selected tasking, resulting in more than 5 stars detected, but an insufficient number of catalog stars were detected to assure a pattern match. The acquisition rate improved slightly from 0400 to 0800 UT as the elevation of tasked objects increased. After the fourth hour telescope control computer restarted, Odin was unable to communicate with the telescope control PC and the Odin executive watchdog timer timed out for the remaining four hours of operation. The inability to monitor real-time operations makes determination of any failure mechanisms difficult.

Legend

Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
212	1	45	0	5	12	3	21	0	N/A
212	1	36	1	7	11	4	13	5	N/A
212	1	32	0	3	8	4	15	6	N/A
212	0.7	18	0	2	7	4	3	1	N/A
Total	3.7	131	1	17	38	15	52	12	36

Table 7 Observation summary for Day 212 (31 Jul 98 UT)

**Figure 25 Azimuth Positions for Day 212 (31 Jul 98 UT)****Figure 26 Elevation Positions for Day 212 (31 Jul 98 UT)**

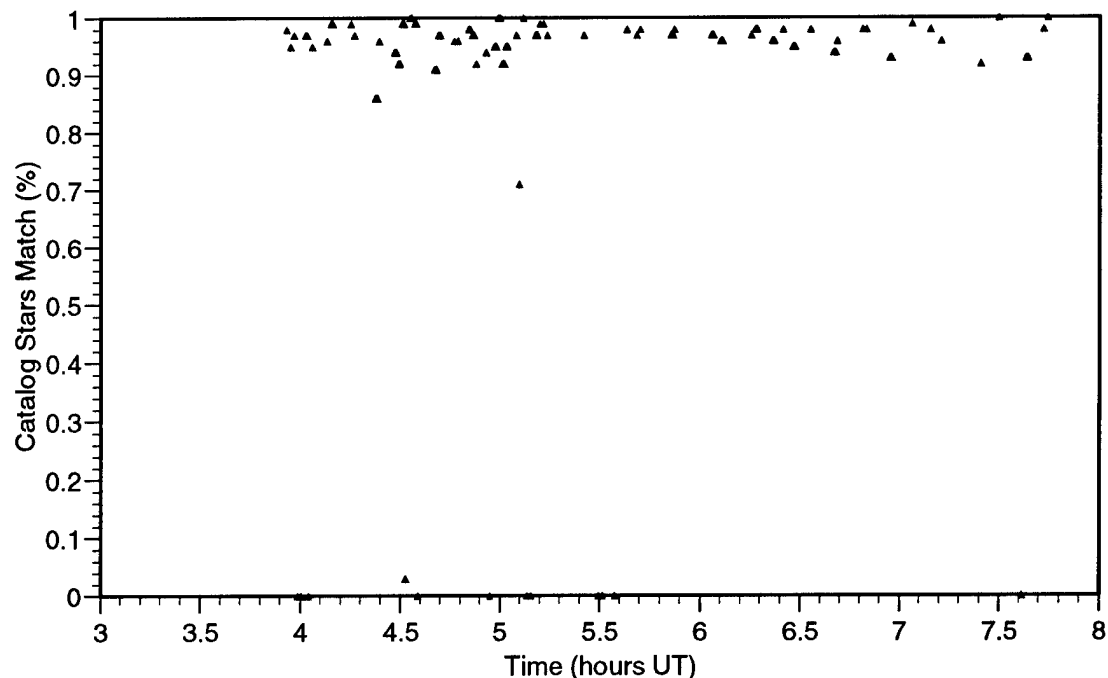


Figure 27 Catalog Star Match Percentage for Day 212 (31 Jul 98 UT)

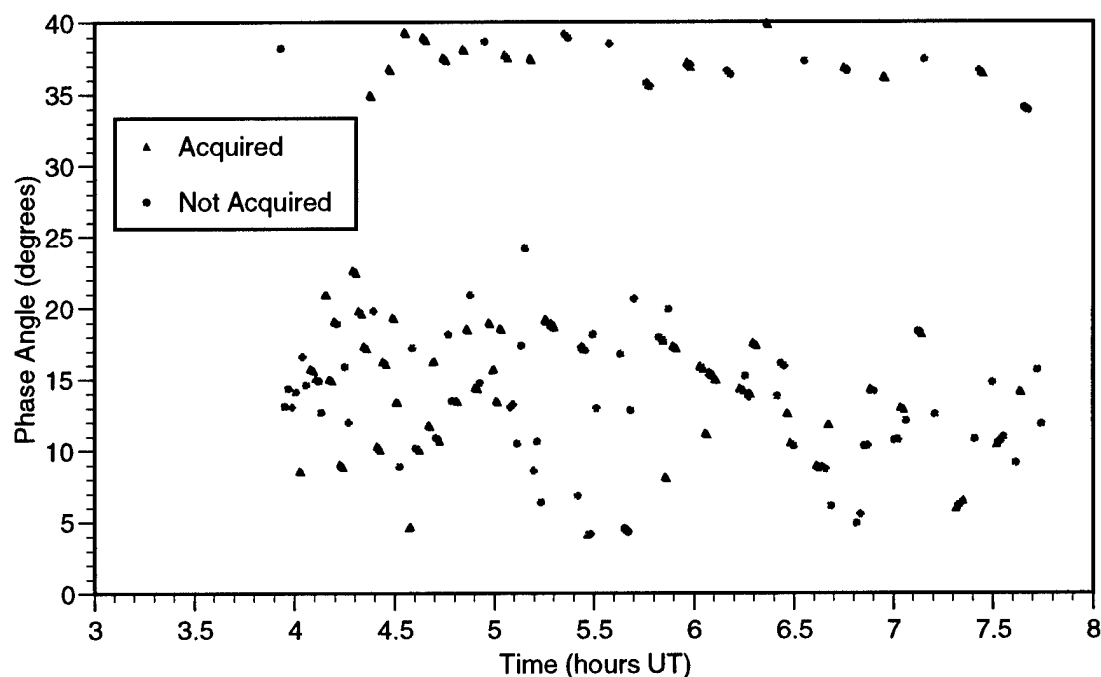


Figure 28 Satellite Phase Angles for Day 212 (31 Jul 98 UT)

H. Day 213 (1 Aug 98 UT)

Operating Environment

Weather: Green
Lunar Background: Moon max elevation: 41° Illumination: 56%

Hardware Condition: Normal

The consistent satellite tasking in the first three hours on the east side of the meridian, depicted in Figure 29, resulting in a throughput of 47 to 55 attempts / hour. The consistent high number of a 'U' miscode is similar to that of the previous night due to the brightness of the moon. Although the telescope is not observing directly at the moon, the combination of a reflective interior dome surface, and open telescope truss, allows the contribution of scattered moonlight to become significant. Six meridian crossings between 0700 and 0800 hours UT reduced the system throughput. After the telescope control PC restart, the tasking returned quickly "nominal" tasking in the west with minimal impact from the initial telescope starting angle of (90°, 30°). There were six more meridian crossings between 0900 and 1000 UT. Repeated tasking of satellite with a 48 day old elset results in multiple Orchestrate scripting errors at 09:45:41, 10:34:52, 10:45:44, and 11:54:03 with resulting watchdog time-outs, greatly reducing throughput. However, during nominal tasking intervals, the acquisition track rate was high.

Legend			
Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
213	1	47	0	9	8	5	20	2	N/A
213	1	54	0	7	8	8	28	10	N/A
213	1	55	0	0	12	10	31	11	N/A
213	1	22	2	6	1	5	7	4	N/A
213	1	51	0	2	11	3	30	8	N/A
213	1	27	0	1	12	0	13	2	N/A
213	0.9	22	0	0	12	1	8	1	N/A
213	0.9	14	0	0	11	0	2	0	N/A
Total	7.4	292	2	25	75	32	139	38	39

Table 8 Observation summary for Day 213 (1 Aug 98 UT)

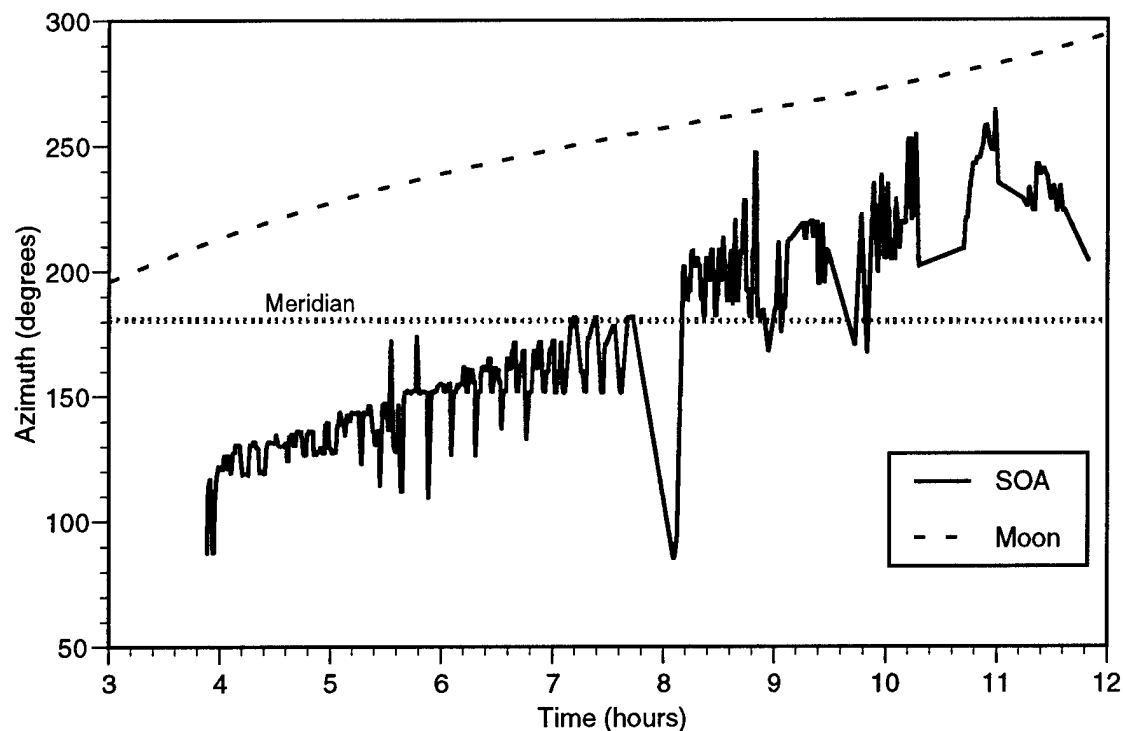


Figure 29 Azimuth positions for Day 213 (1 Aug 98 UT)

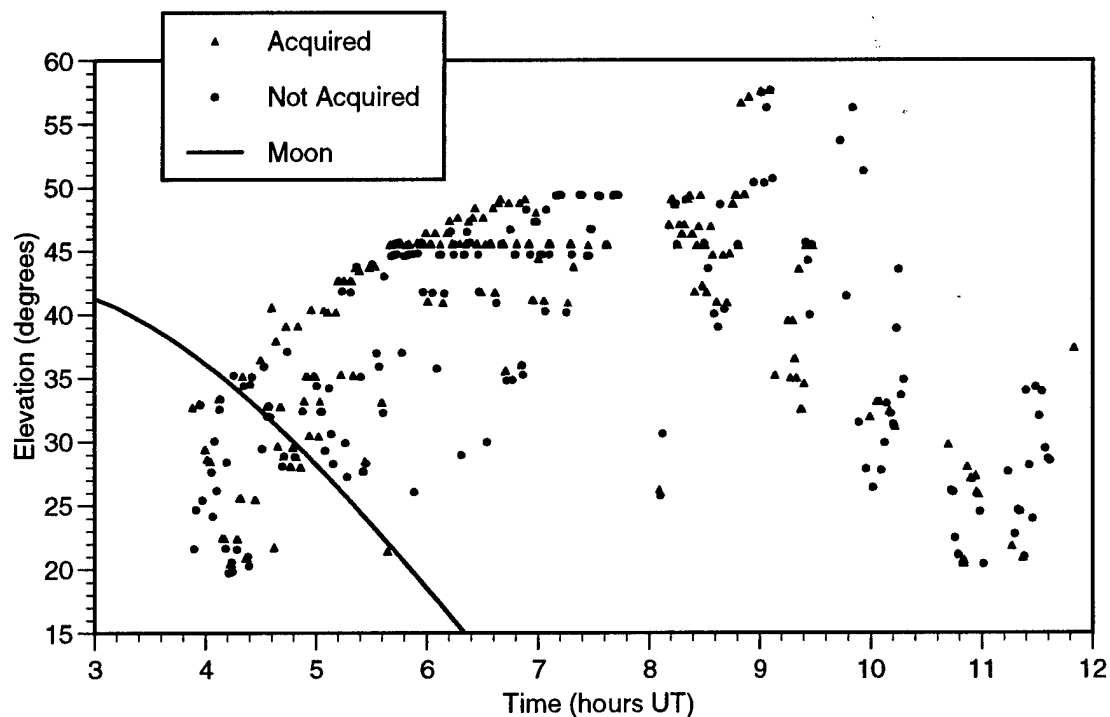


Figure 30 Elevation Positions for Day 213 (1 Aug 98 UT)

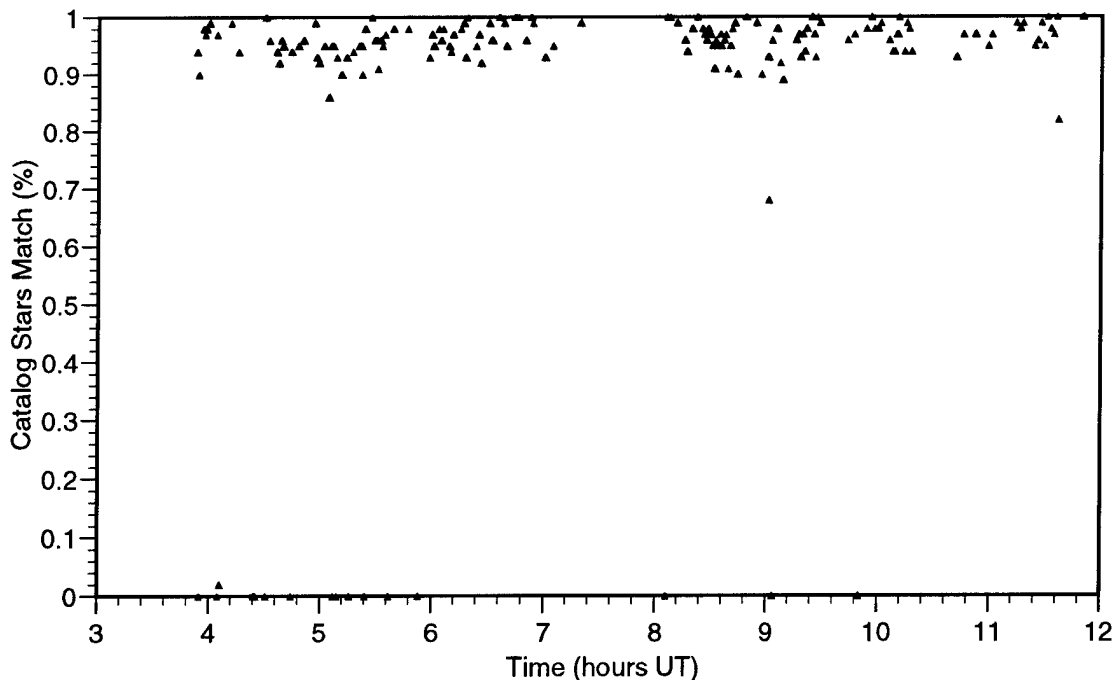


Figure 31 Catalog Star Match Percentage for Day 213 (1 Aug 98 UT)

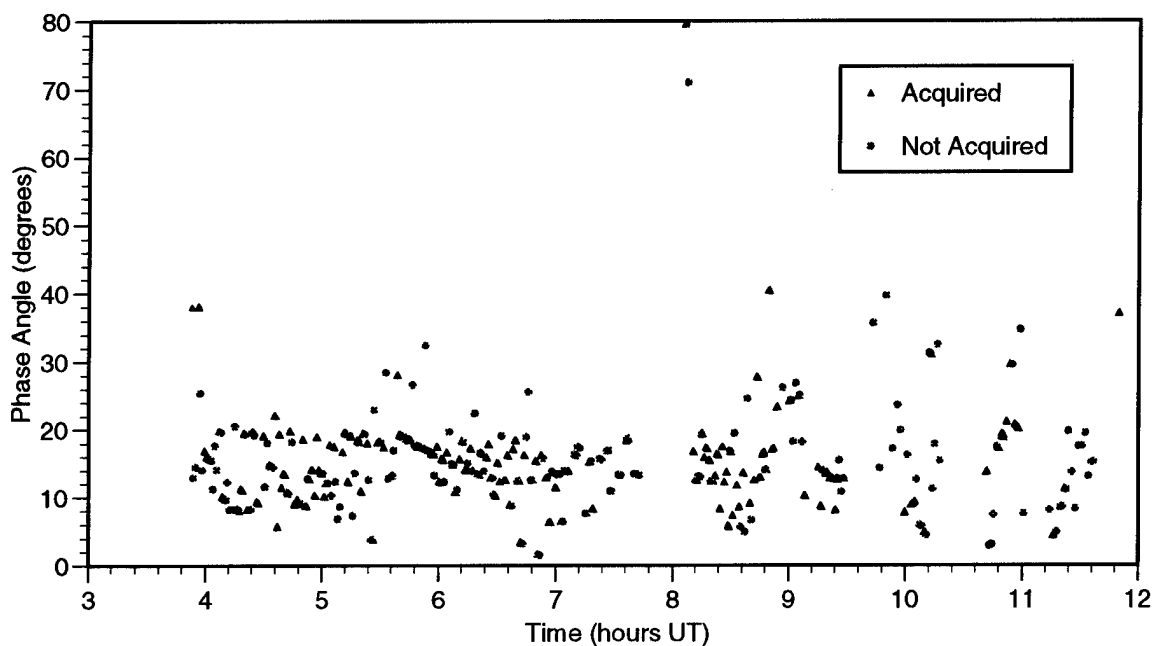


Figure 32 Satellite Phase Angles for Day 213 (1 Aug 98 UT)

I. Day 216 (4 Aug 98 UT)

Operating Environment

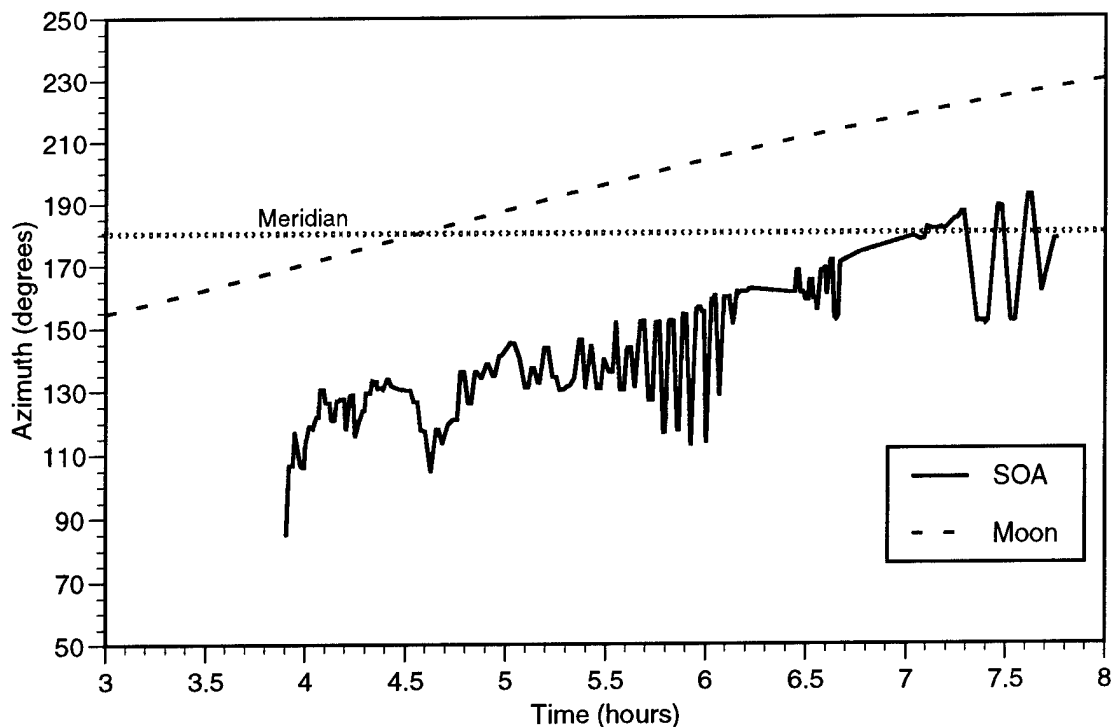
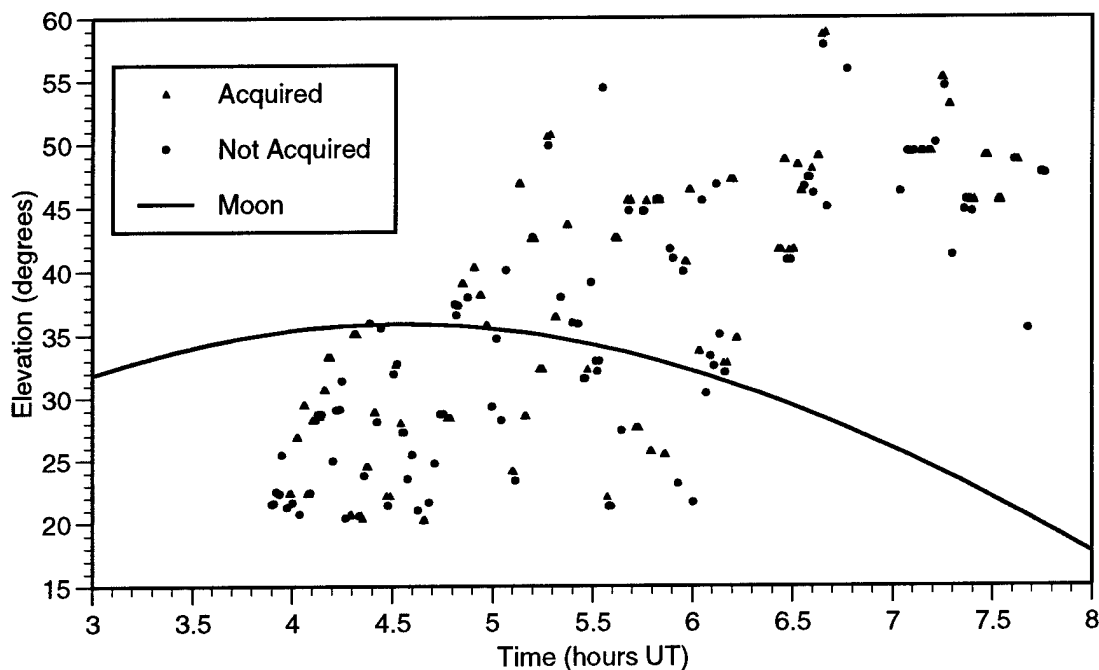
Weather:	Green
Lunar Background:	Moon max elevation: 35° Illumination: 83%
Hardware Condition:	Normal

Observation throughput was high in the first two hours of operation. Watchdog time-outs, due to tasking a satellite with a 68 day-old else at 06:25:42 and 06:59:58, resulted in the 10 and 20 minute gaps in azimuth and elevation motions shown in Figure 33 and Figure 34, respectively. Several periods of close moon proximity in elevation results in insufficient number of catalog star detected and 'U' miscode reporting between 0400 and 0600 UT, as seen in Figure 35. However, the weather condition for most of the night appears "green." After its four-hour restart, the telescope control PC did not respond to scripting by Odin. Without onsite or remote monitoring of SOA system operation, the causes for these failures are unknown.

Legend			
Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
216	1	40	0	7	13	4	13	0	N/A
216	1	42	0	7	8	3	21	9	N/A
216	0.8	25	0	2	8	2	11	0	N/A
216	0.9	21	3	0	4	1	15	8	N/A
Total	3.7	128	3	16	33	10	60	17	35

Table 9 Observation summary for Day 216 (4 Aug 98 UT)

**Figure 33 Azimuth Positions for Day 216 (4 Aug 98 UT)****Figure 34 Elevation Positions for Day 216 (4 Aug 98 UT)**

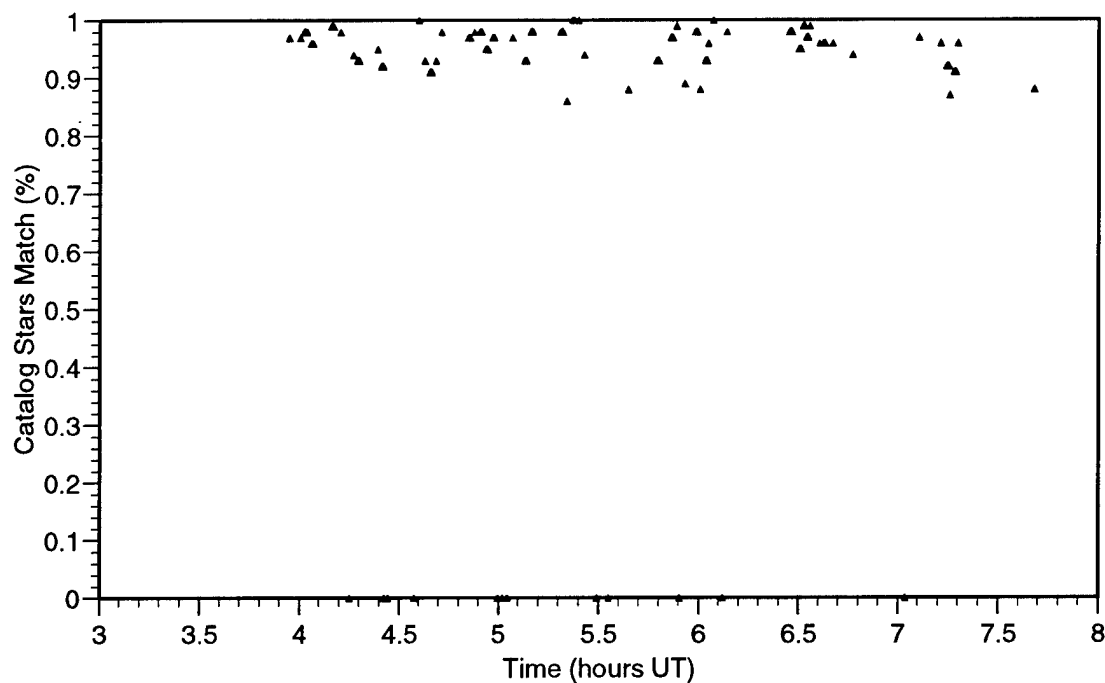


Figure 35 Catalog Star Match Percentage for Day 216 (4 Aug 98 UT)

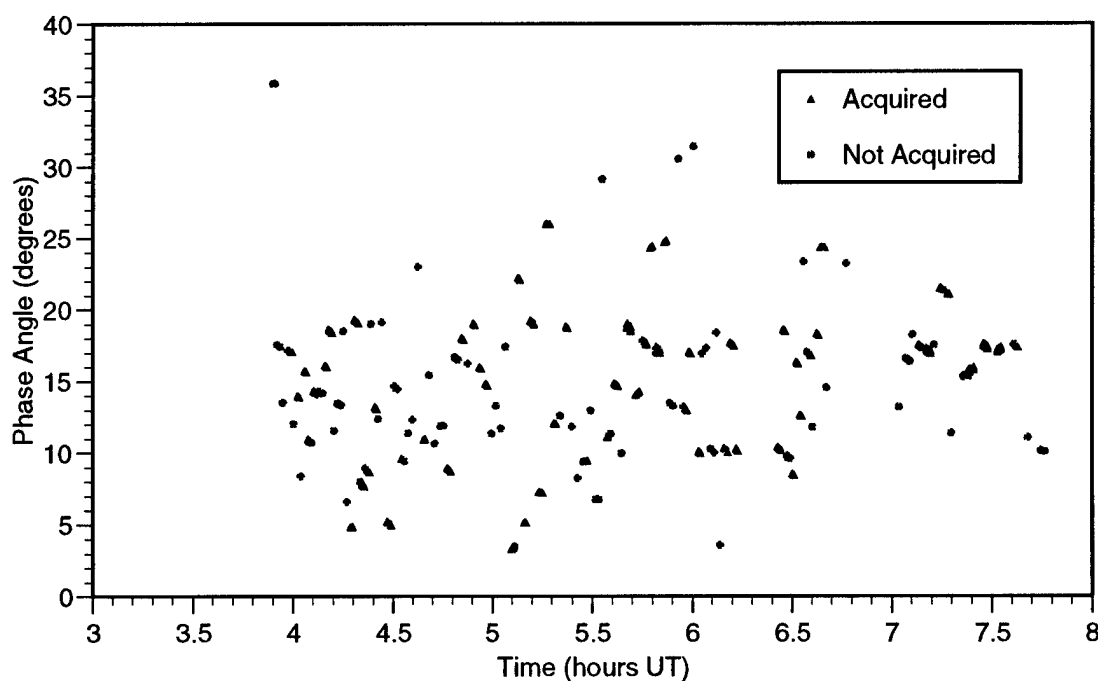


Figure 36 Satellite Phase Angles for Day 216 (4 Aug 98)

J. Day 217 (5 Aug 98 UT)

Operating Environment

Weather: Green
Lunar Background: Moon max elevation: 35° Illumination: 90%

Hardware Condition: Normal

For the first three observations of the night, ODSP scheduled SOA for objects in the east with good phase angles. However, the fourth tasked object is in the west at 230°. This tasking anomaly results from reporting observations from the last images collected on the previous day, 4 Aug 98 UT. In addition, MIT/LL did not completely initialize the SkyMap software in ODSP used to maintain current satellite positions at the start of operations. Consequently, the selection of satellites for tasking was limited. For the next three hours between 0400 and 0700 hours UT, the tasking varies 40° largely around the meridian and the moon. Many of these observations are at low elevation and large phase angle as shown in Figure 38 and Figure 40, respectively. These factors along with bright lunar sky background result in the low throughput and very poor acquisition success rate during this period.

Starting at 0650 hours, azimuth slewing across the meridian disappears, and the attempt rate increases to 42 attempts / hour. With the higher elevation angles and improved phase angles, the acquisition rate increases accordingly. After the four-hour restart, the fixed telescope-pointing angle used in the schedule and reschedule commands, result in another series of large azimuth motions for the remainder of the night. Throughput rates remain at a low 23 to 35 attempts / hour. Poor phase angles and low elevations reduce acquisition rates. Small lunar angles contribute to 31 'U' miscodes reported along with the known error in The Sky software. Despite large lunar sky background, the catalog star match percentage, displayed in Figure 39, remains near 90%, except reductions between 80% to 90% when the SOA telescope points within 40° of the moon.

Legend			
Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
217	1	20	0	8	9	0	3	0	N/A
217	1	17	0	6	6	2	2	0	N/A
217	1	23	0	5	10	1	5	1	N/A
217	0.7	42	0	0	6	3	31	11	N/A
217	1	33	1	4	17	1	11	3	N/A
217	1	32	0	0	17	3	12	2	N/A
217	1	35	0	4	20	0	10	1	N/A
217	0.7	23	0	4	14	1	4	1	N/A
Total	7.3	225	1	31	99	11	78	19	31

Table 10 Observation summary for Day 217 (5 Aug 98 UT)

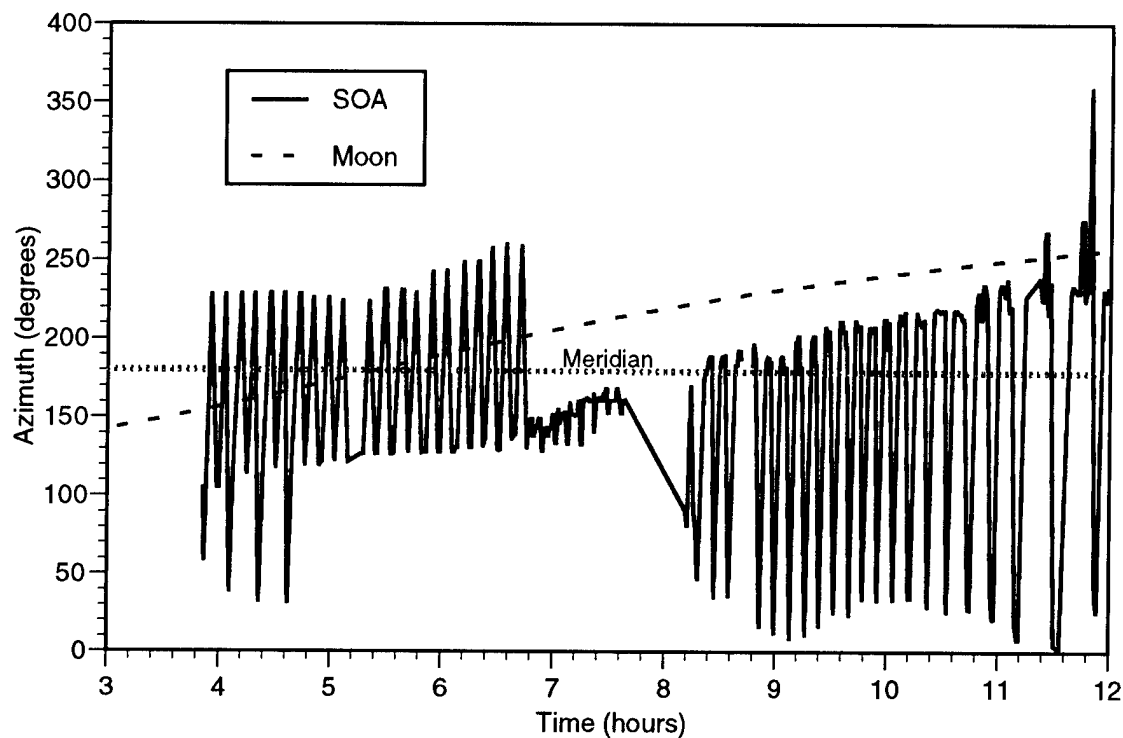


Figure 37 Azimuth Positions for Day 217 (5 Aug 98 UT)

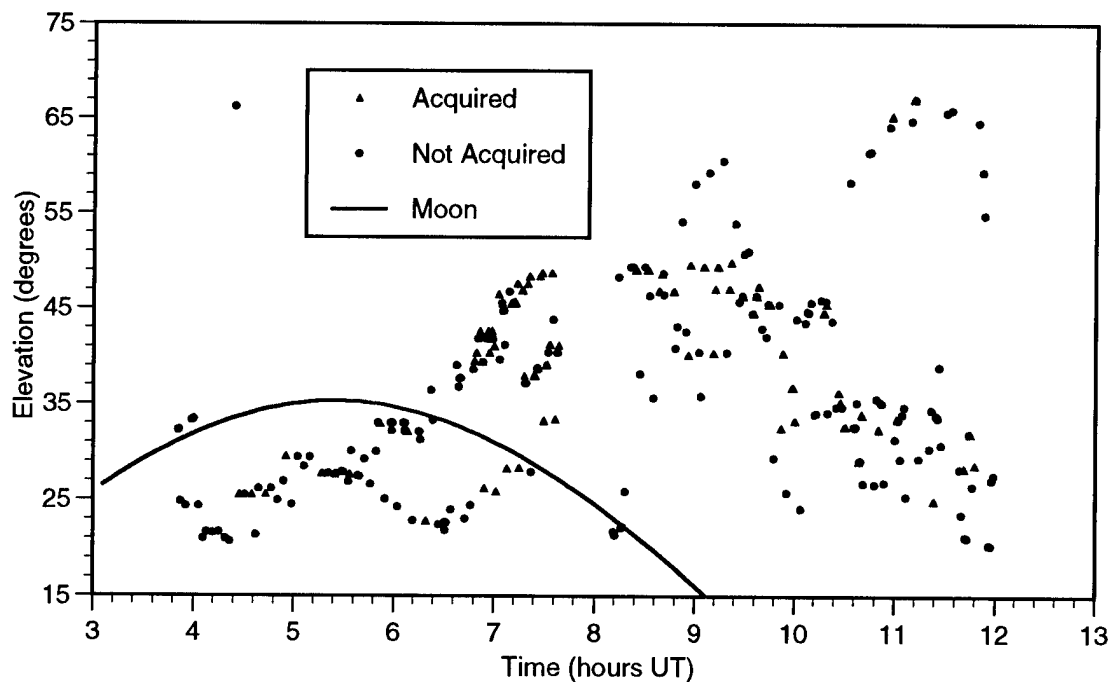


Figure 38 Elevation Positions for Day 217 (5 Aug 98 UT)

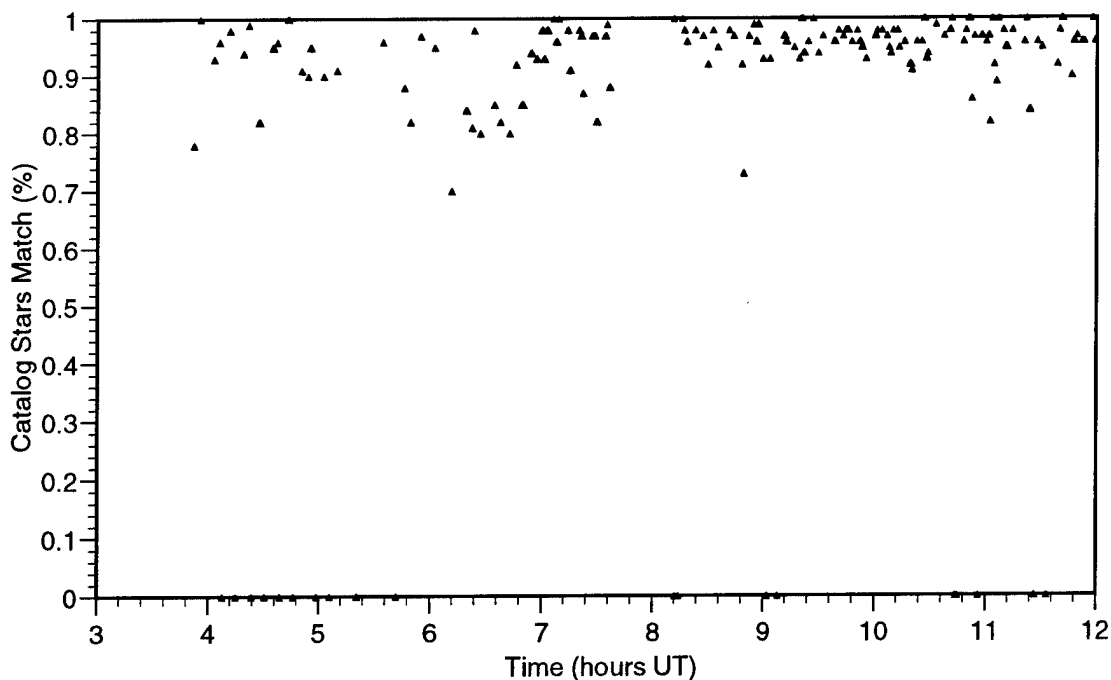


Figure 39 Catalog Star Match Percentage for Day 217 (5 Aug 98 UT)

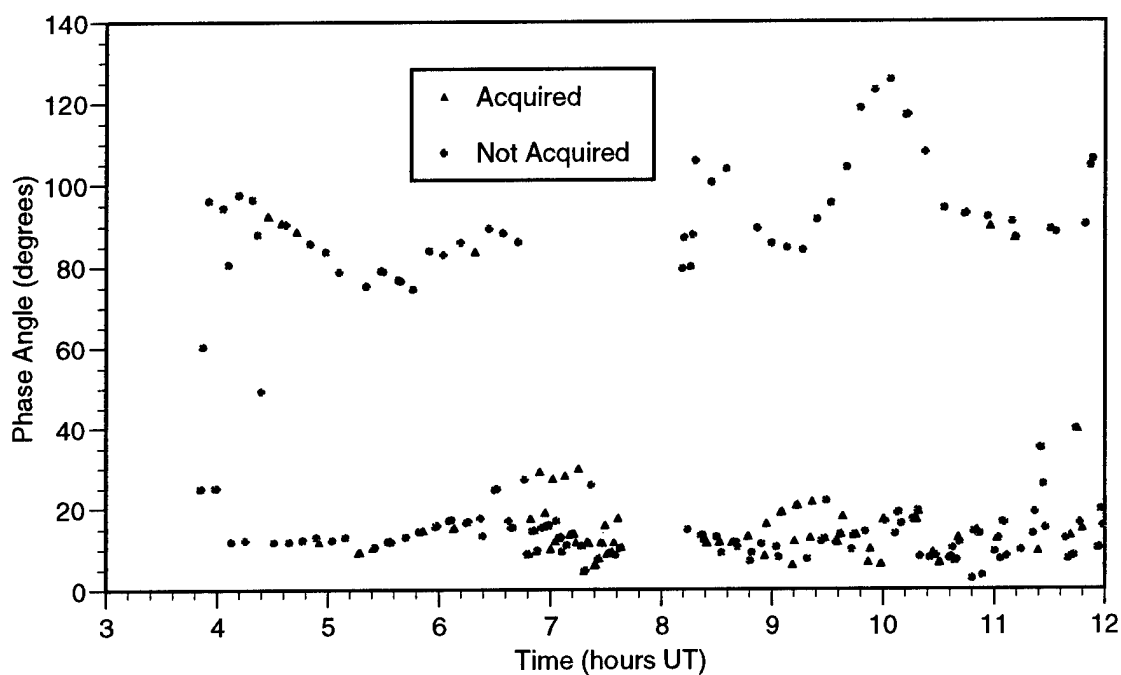


Figure 40 Satellite Phase Angles for Day 217 (5 Aug 98 UT)

K. Day 218 (6 Aug 98 UT)

Operating Environment

Weather: Green
Lunar Background: Moon max elevation: 35° Illumination: 96%

Hardware Condition: Normal

Similar to Day 217 (5 Aug 98 UT), the first three tasked satellites were at 90° azimuth and 45° elevation, while the fourth object is tasked at 182° azimuth based on metrics reported from a previous night's observation. Due to operations issues, throughput in the first two hours ranged from 36 to 41 attempts / hour, but reduced to 30 attempts / hour as the number of meridian crossings increased. This effect on throughput repeats in the last three hours of operations from 0900 to 1200 hours UT. A separation angle of 40° to a nearly full moon had strong effects on the percentage of catalog stars matched with 35 'U' miscodes and some percentage of star matches less than 80%. This bright lunar sky background, low elevations, and phase angles ranging from 60° to 120° contributed to the poor acquisition success rate seen throughout the night.

Legend	
Hrs	:Time duration for statistics in hours
W	:Observations in red weather condition
N	:Not acquired
Acq	:Full acquisition (5 or more obs)
Att/hr	:# Att / Total observation time
#Att	:Total attempts excluding red weather
U	:Image header coordinate error
P	:Partial acquisition (<5 marks)
AddAcq	:Additional objects in tasked FOV

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
218	1	36	1	1	20	0	14	3	N/A
218	1	41	1	1	29	0	10	0	N/A
218	1	30	0	5	9	3	9	0	N/A
218	0.9	41	0	4	13	3	17	3	N/A
218	1	40	1	8	14	3	11	6	N/A
218	0.9	33	0	9	11	2	7	0	N/A
218	1	26	1	5	11	0	8	2	N/A
218	0.9	24	0	2	19	0	3	0	N/A
Total	7.7	271	4	35	126	13	79	14	35

Table 11 Observation summary for Day 218 (6 Aug 98 UT)

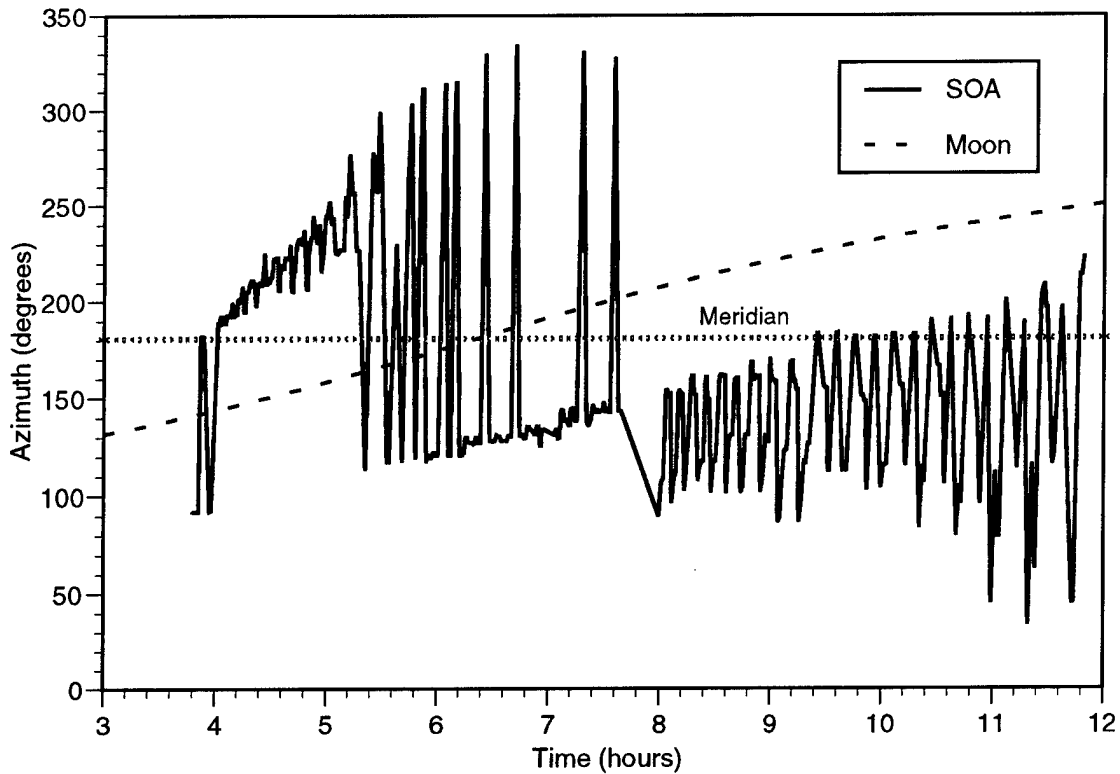


Figure 41 Azimuth Positions for Day 218 (6 Aug 98 UT)

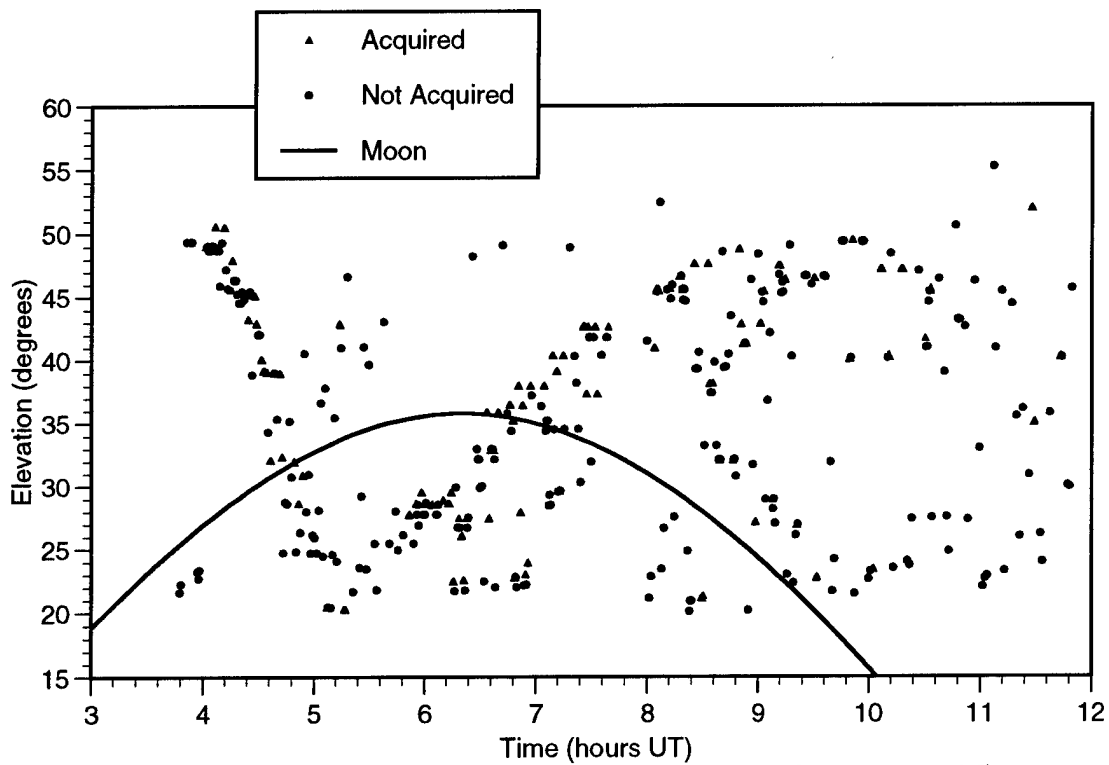


Figure 42 Elevation Positions for Day 218 (6 Aug 98 UT)

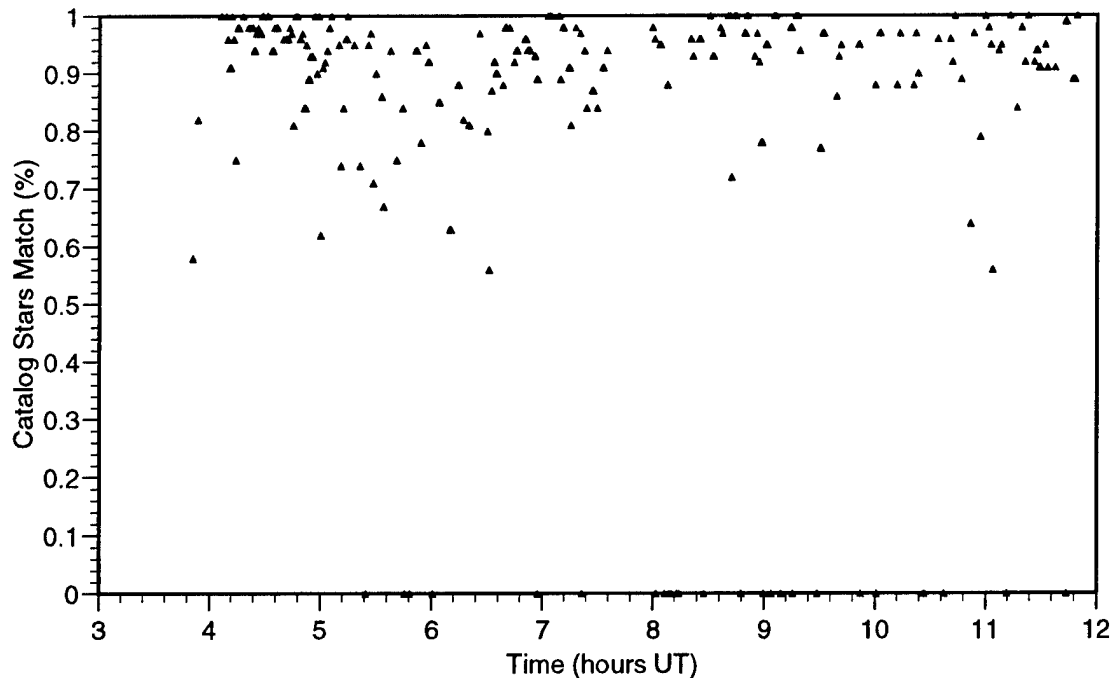


Figure 43 Catalog Star Match Percentage for Day 218 (6 Aug 98 UT)

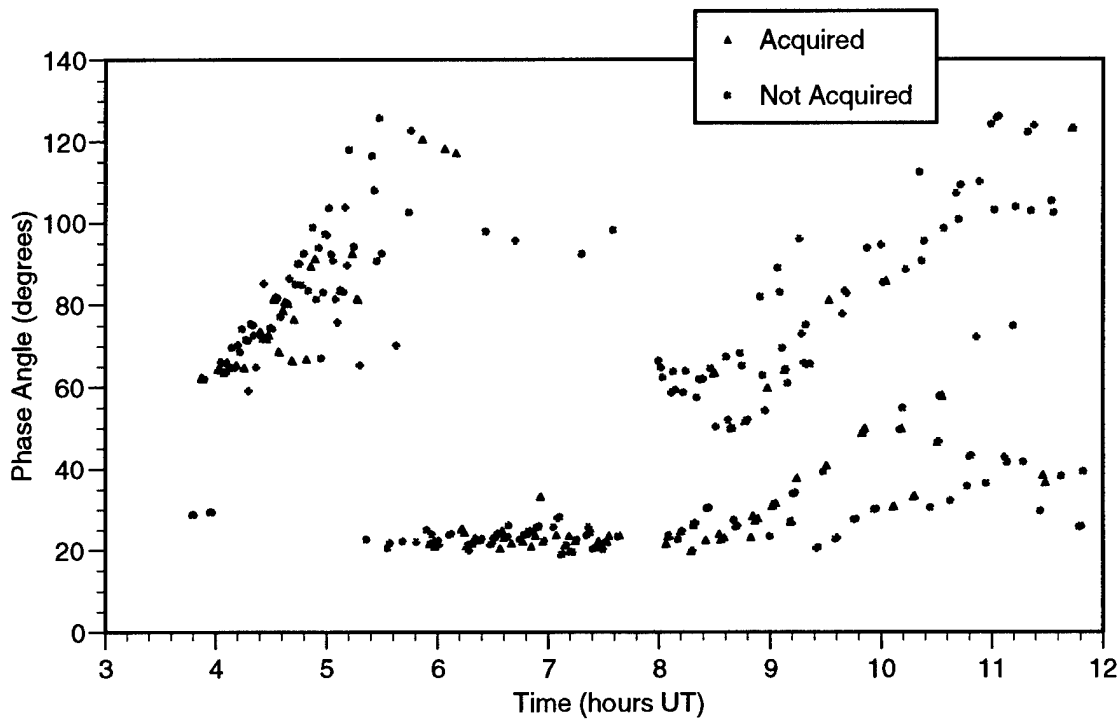


Figure 44 Satellite Phase Angles for Day 218 (6 Aug 98 UT)

L. Day 219 (7 Aug 98 UT)

Operating Environment

Weather: Green

Lunar Background: Moon max elevation: 37° Illumination: 99%
 Hardware Condition: Dome shutter failed to open after 4 hour reboot

The throughput in the first half of the night (0300-0700 UT) is OK, but the acquisition numbers are low due to high phase angles of the tasked objects, well above 60 degrees, see Figure 48. We considered the weather yellow in this situation due to the full moon background, Figure 45, Figure 46, and Figure 47. The telescope was operational, but the dome shutter did not open in the second half of the night (0800-1200 UT). We found the problem to be in the misalignment of the dome homing system and lack of a feedback system. Currently, the dome system initiates an open or close command without confirming the true status of the shutter. We reported the problem back to the manufacturer and the manufacturer will implement a feedback control system, giving dome open and close status.

Legend			
Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
219	1	35	0	4	25	0	6	0	N/A
219	1	39	2	2	26	1	10	1	N/A
219	1	25	0	3	18	0	4	0	N/A
219	0.9	23	2	5	15	0	3	0	N/A
219	1	11	25	11	0	0	0	0	N/A
219	1	7	23	7	0	0	0	0	N/A
219	0.9	9	22	9	0	0	0	0	N/A
219	0.9	9	14	9	0	0	0	0	N/A
Total	7.6	158	88	50	84	1	23	1	21

Table 12 Observation summary for Day 219 (7 Aug 98 UT)

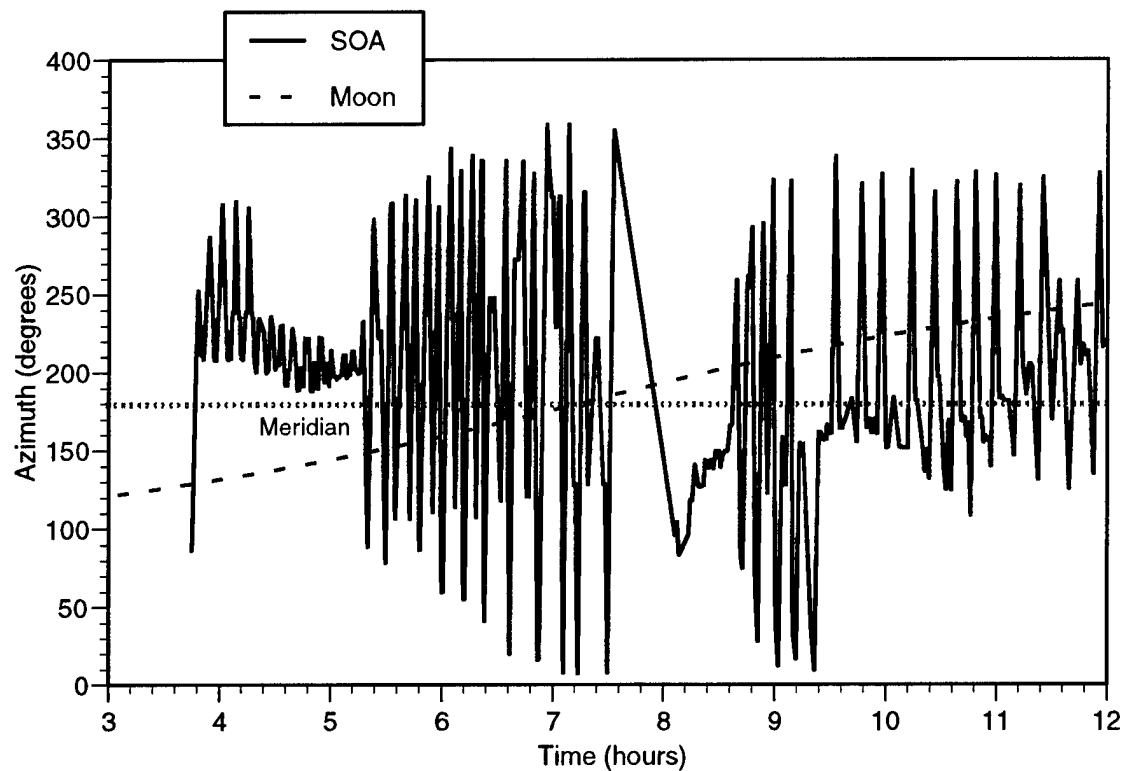


Figure 45 Azimuth Positions for Day 219 (7 Aug 98 UT)

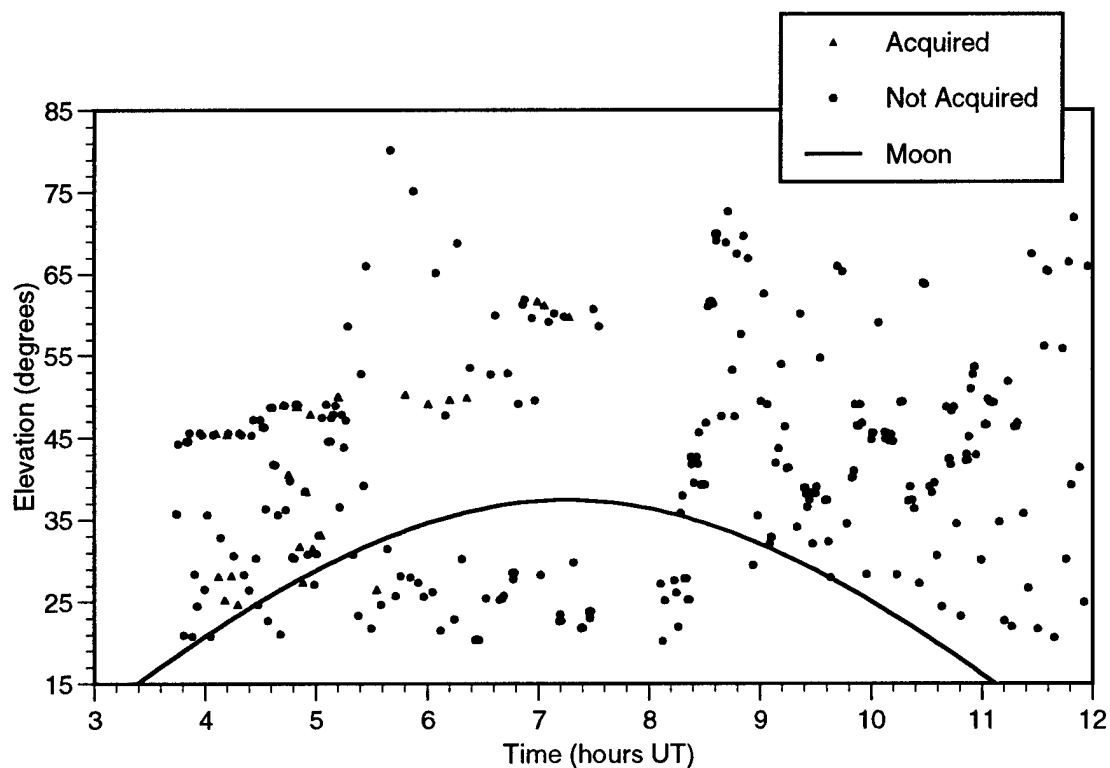


Figure 46 Elevation Positions for Day 219 (7 ug 98 UT)

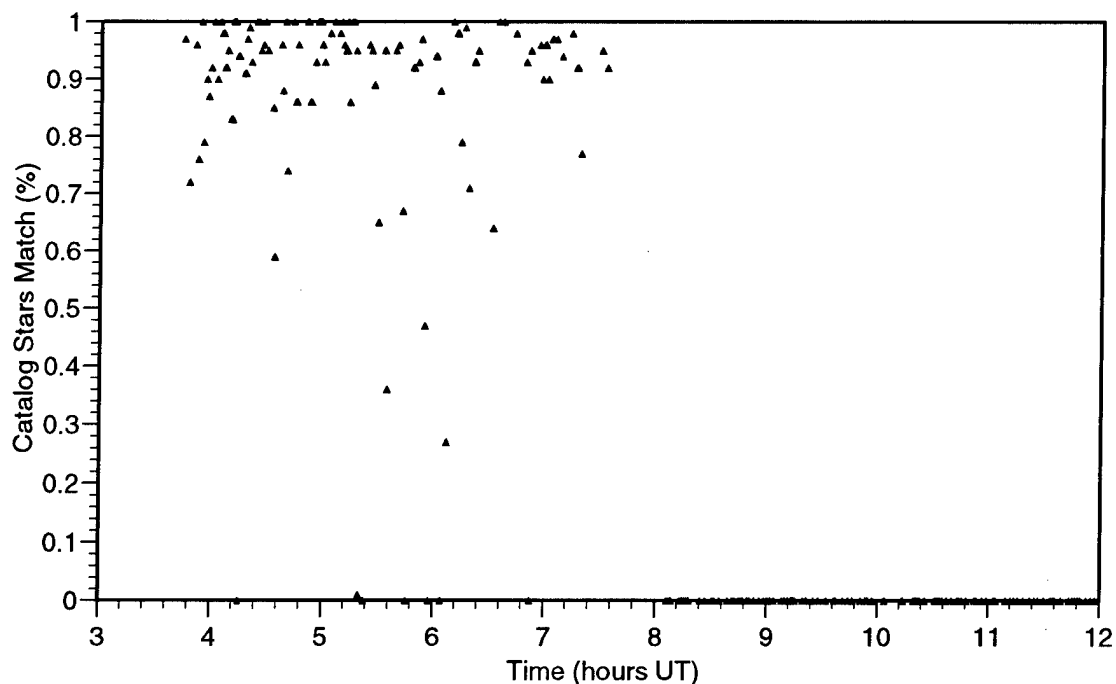


Figure 47 Catalog Star Match Percentage for Day 219 (7 Aug 98 UT)

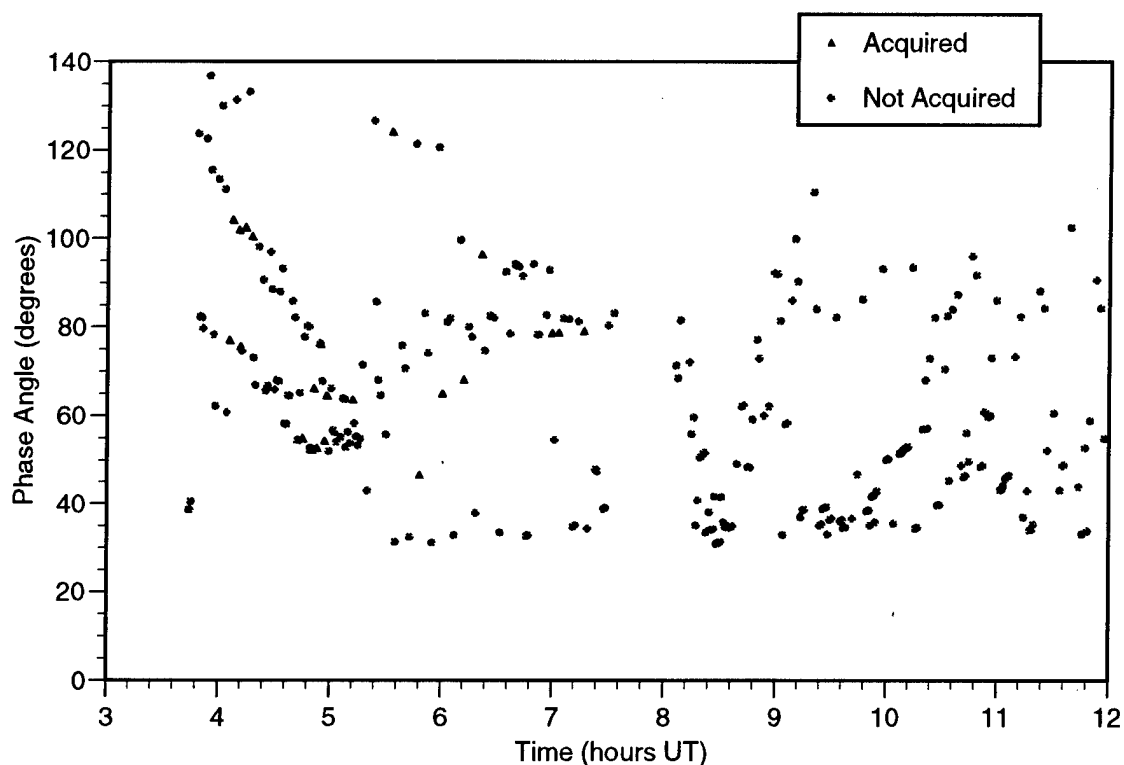


Figure 48 Satellite Phase Angles for Day 219 (7 Aug 98 UT)

M. Day 223 (11 Aug 98 UT)

Operating Environment

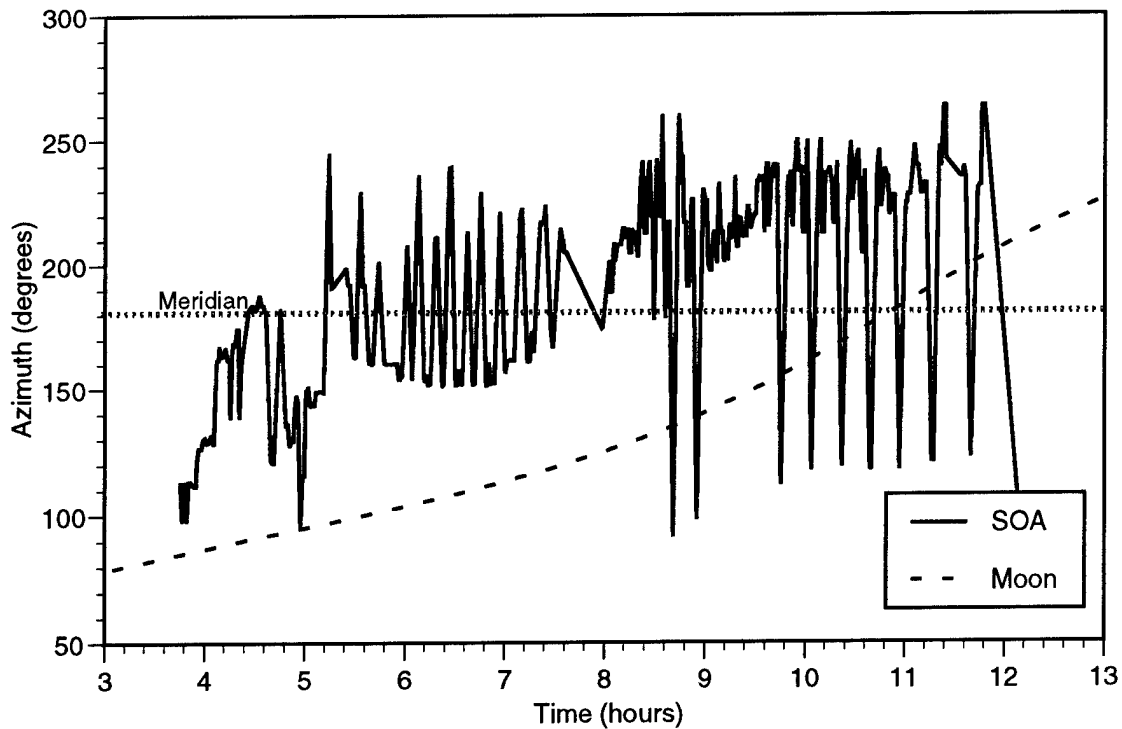
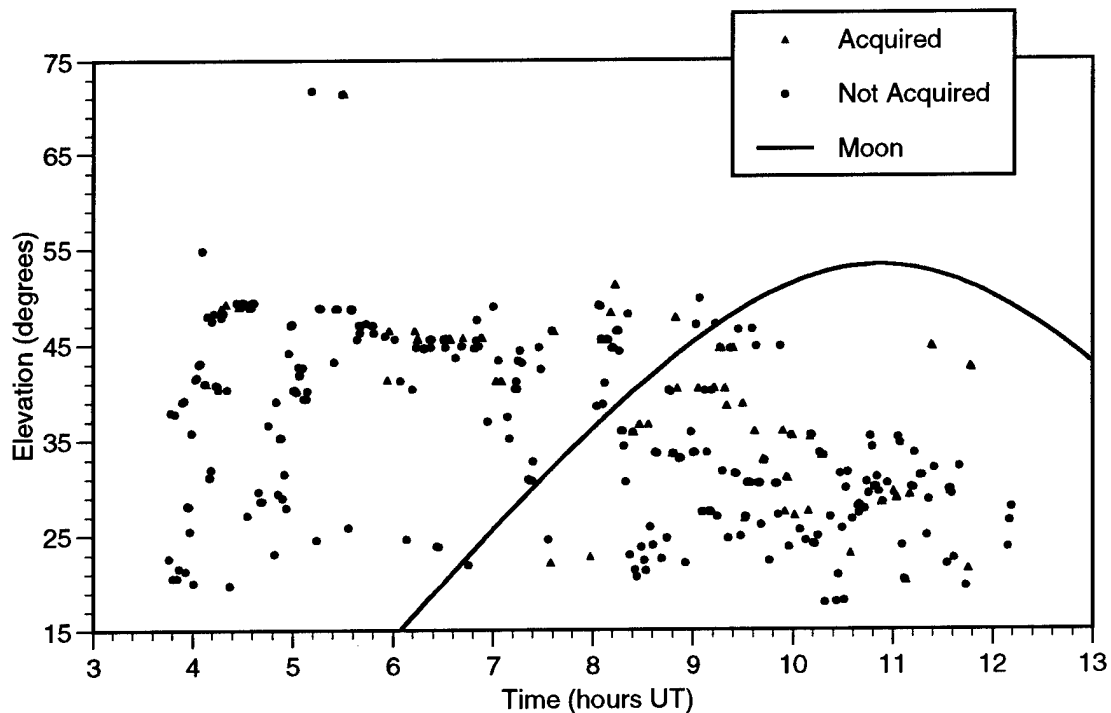
Weather: Periodic red/yellow weather
 Lunar Background: Moon max elevation: 53° Illumination: 88%
 Hardware Condition: Normal

The lower number of acquisitions and attempts are due to red/yellow weather, poorly scheduled satellites (mount motion across the meridian), Figure 49, and objects observed close to the moon throughout the entire night, Figure 50. The skies were not clear during the whole night of observations, Figure 51.

Legend	
Hrs	:Time duration for statistics in hours
W	:Observations in red weather condition
N	:Not acquired
Acq	:Full acquisition (5 or more obs)
Att/hr	:# Att / Total observation time
#Att	:Total attempts excluding red weather
U	:Image header coordinate error
P	:Partial acquisition (<5 marks)
AddAcq	:Additional objects in tasked FOV

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
223	1	21	19	11	5	2	2	1	N/A
223	1	10	19	5	4	1	0	0	N/A
223	1	26	2	6	6	2	11	7	N/A
223	0.9	18	3	3	9	3	3	0	N/A
223	1	32	7	3	18	3	8	2	N/A
223	1	36	4	1	21	2	10	0	N/A
223	1	34	0	1	25	2	5	1	N/A
223	1	23	0	2	13	1	6	0	N/A
223	0	1	0	1	0	0	0	0	N/A
Total	7.8	201	54	33	101	16	45	11	26

Table 13 Observation summary for Day 223 (11 Aug 98 UT)

**Figure 49 Azimuth Positions for Day 223 (11 Aug 98 UT)****Figure 50 Elevation Positions for Day 223 (11 Aug 98 UT)**

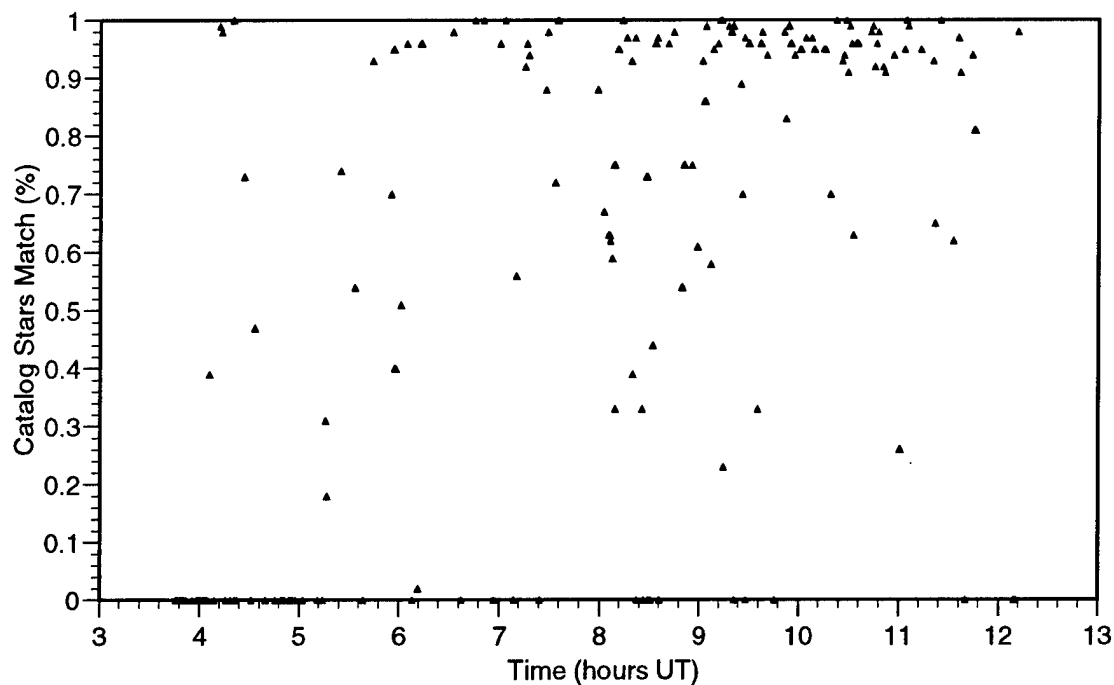


Figure 51 Catalog Star Match Percentage for Day 223 (11 Aug 98 UT)

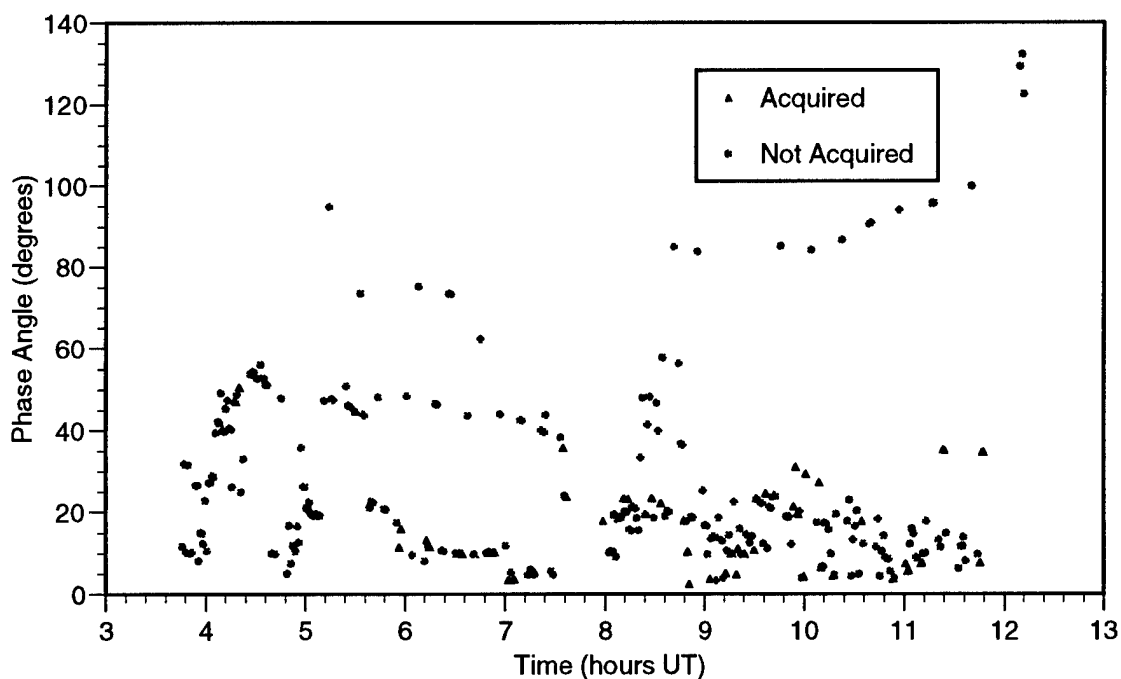


Figure 52 Satellite Phase Angles for Day 223 (11 Aug 98 UT)

N. Day 213 (1 Aug 98 UT)

Operating Environment

Weather: Red/yellow weather
Lunar Background: Moon max elevation: 58° Illumination: 76%

Hardware Condition: Normal

We attribute the lower number of acquisitions on Day 224 to red/yellow weather and observations with a high lunar background. The first half of the night shows low acquisition numbers due to red/yellow weather. During the fourth, fifth, and sixth hours, there was an increase in acquisition and attempts due to the nominal scheduling (minimal meridian crossing), Figure 53, and high observing elevations, Figure 54. The weather was red/yellow throughout the night.

Legend			
Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
224	1	17	15	10	7	0	0	0	N/A
224	1	9	18	9	0	0	0	0	N/A
224	1	21	3	9	5	1	6	0	N/A
224	0.9	37	1	1	8	3	25	13	N/A
224	1	32	1	3	5	5	13	6	N/A
224	1	50	0	1	28	2	19	2	N/A
224	1	48	0	0	35	1	12	0	N/A
224	1	24	0	2	20	0	2	0	N/A
Total	7.8	238	38	35	108	12	77	21	30

Table 8 Observation summary for Day 213 (1 Aug 98 UT)

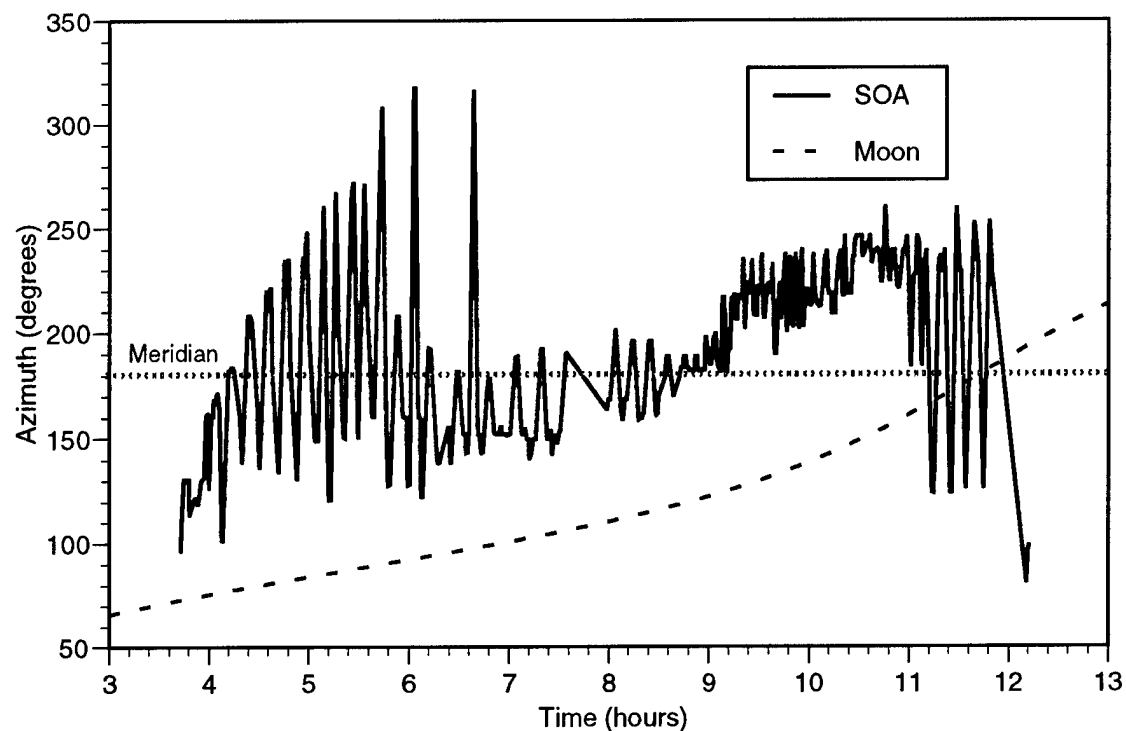


Figure 53 Azimuth Positions for Day 224 (12 Aug 98 UT)

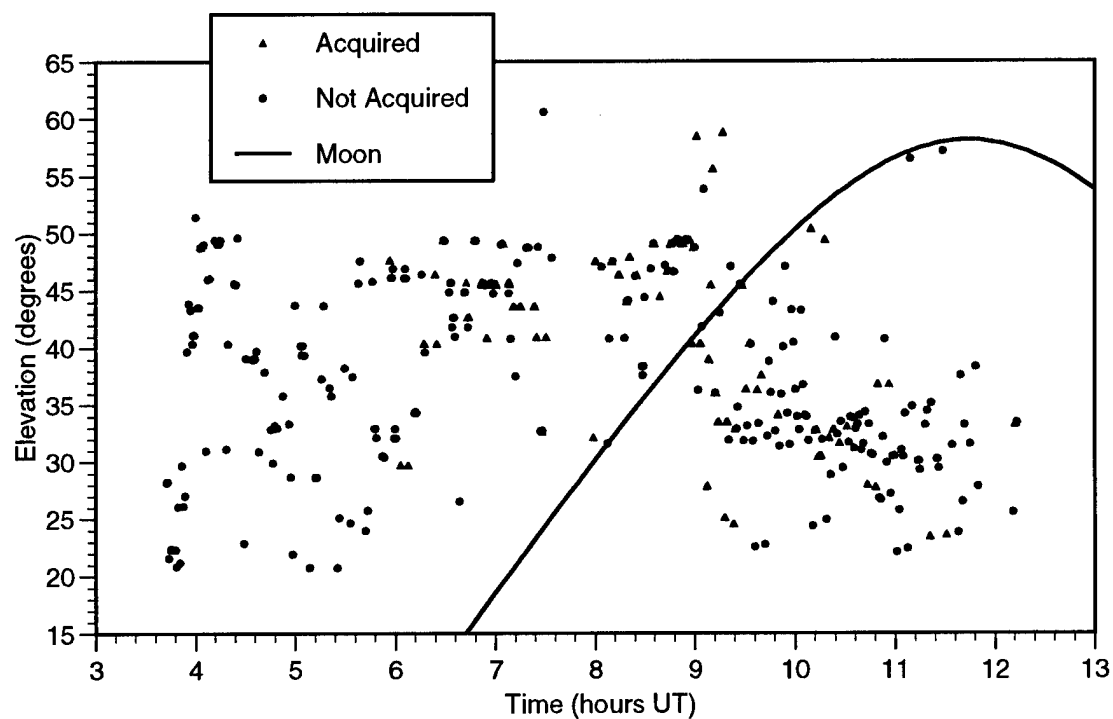


Figure 54 Elevation Positions for Day 224 (12 Aug 98 UT)

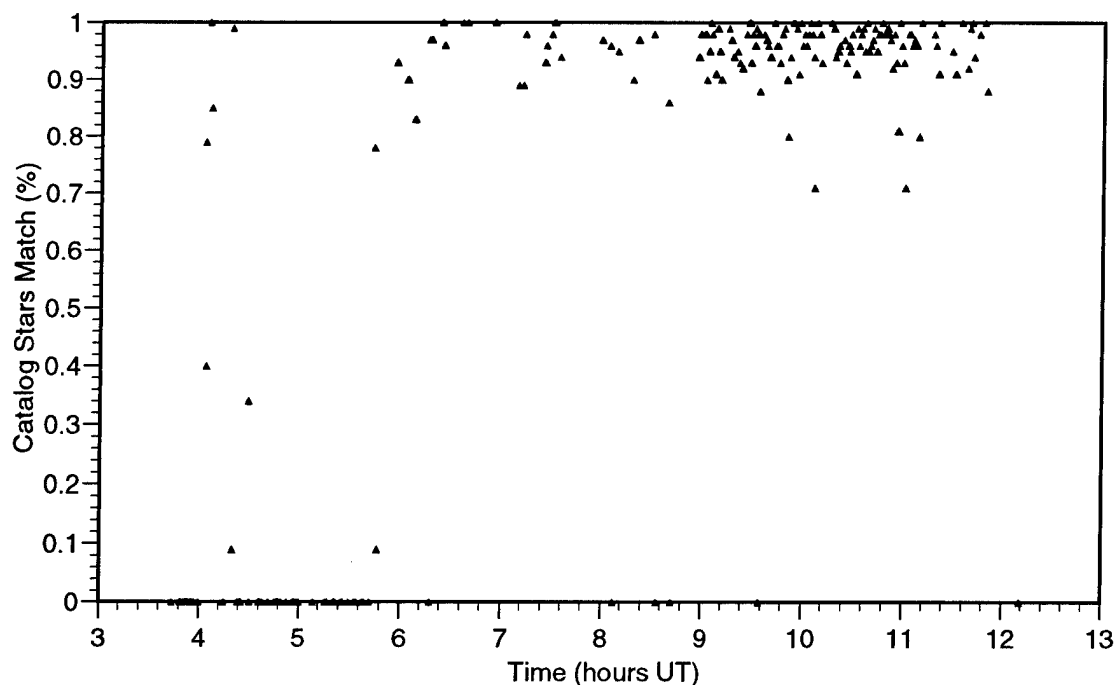


Figure 55 Catalog Star Match Percentage for Day 224 (12 Aug 98 UT)

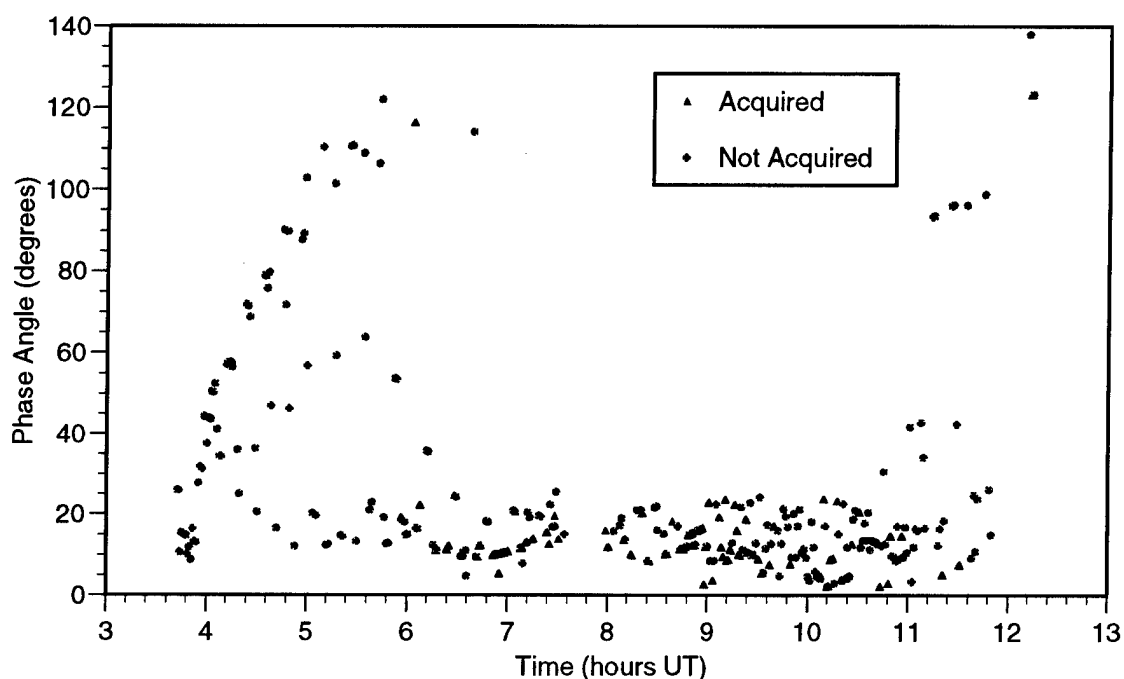


Figure 56 Satellite Phase Angles for Day 224 (12 Aug 98 UT)

O. Day 225 (13 Aug 98 UT)

Operating Environment

Weather: Red/yellow weather between 05 and 07 UT
Lunar Background: Moon max elevation: 62° Illumination: 65%

Hardware Condition: Normal

Operations were normal during the first 2 hours. There is an apparent weather change between the 2nd and 3rd hours (red weather). Acquisitions rolled down due to high lunar background. The skies appeared to be yellow throughout the night and red between the 2nd and 3rd hour, Figure 59. ODSP scheduled good object phase angles throughout the night. This is a good example of an efficiently scheduled and nominal operational night, unfortunately the weather was yellow and red resulting in a low number of acquisitions.

Legend

Hrs	:Time duration for statistics in hours	#Att	:Total attempts excluding red weather
W	:Observations in red weather condition	U	:Image header coordinate error
N	:Not acquired	P	:Partial acquisition (<5 marks)
Acq	:Full acquisition (5 or more obs)	AddAcq	:Additional objects in tasked FOV
Att/hr	:# Att / Total observation time		

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
225	1	41	0	6	14	3	18	1	N/A
225	1	41	2	4	10	5	17	6	N/A
225	1	11	17	6	2	1	2	0	N/A
225	1	11	9	3	7	0	1	0	N/A
225	1	32	0	4	6	5	17	3	N/A
225	1	47	1	1	23	4	18	3	N/A
225	1	44	0	1	36	0	7	0	N/A
225	0.9	41	1	0	29	0	12	1	N/A
225	0	1	0	0	1	0	0	0	N/A
Total	7.8	269	30	25	128	18	92	14	35

Table 15 Observation summary for Day 225 (13 Aug 98 UT)

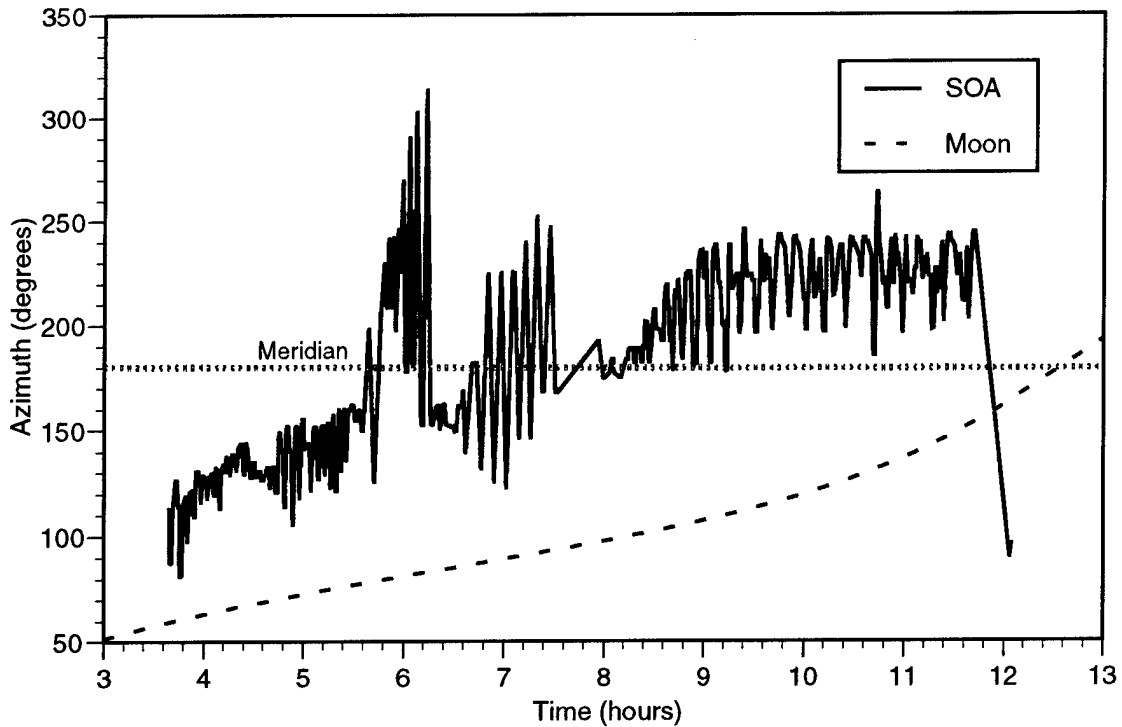


Figure 57 Azimuth Positions for Day 225 (13 Aug 98 UT)

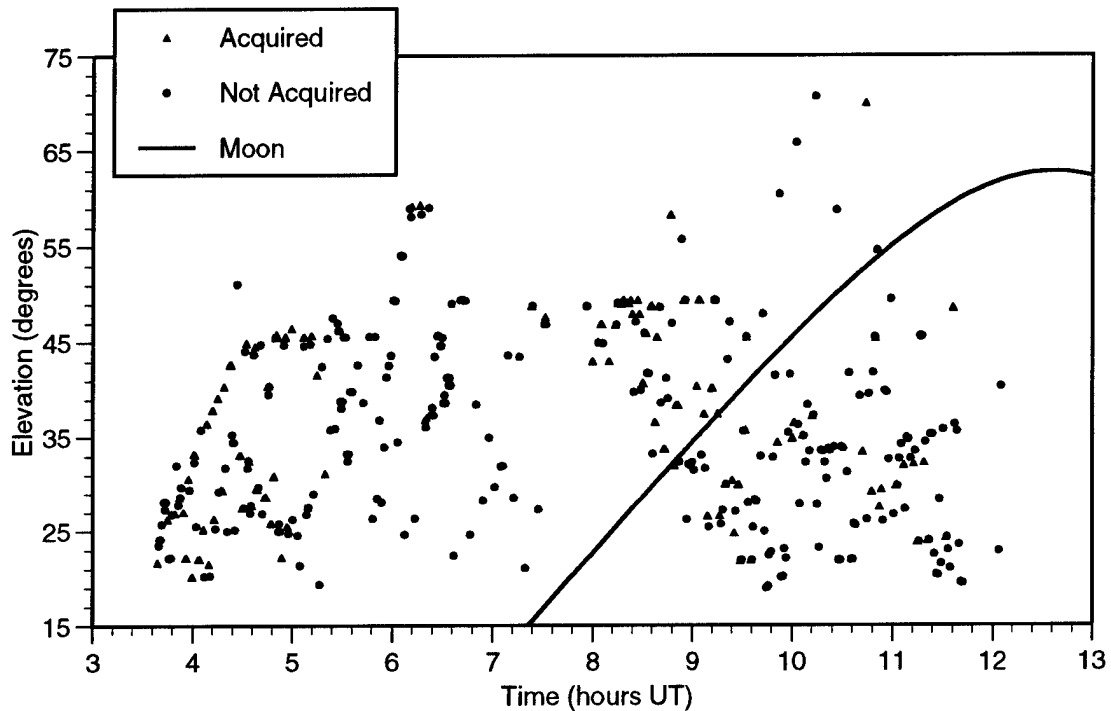


Figure 58 Elevation Positions for Day 225 (13 Aug 98 UT)

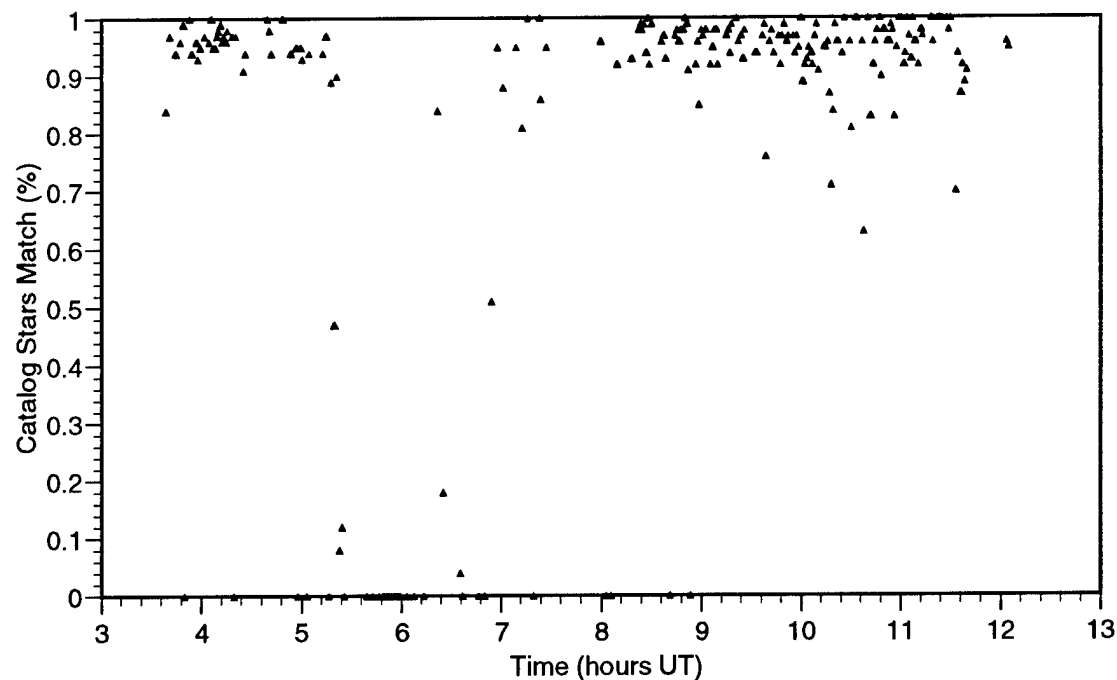


Figure 59 Catalog Star Match Percentage for Day 225 (13 Aug 98 UT)

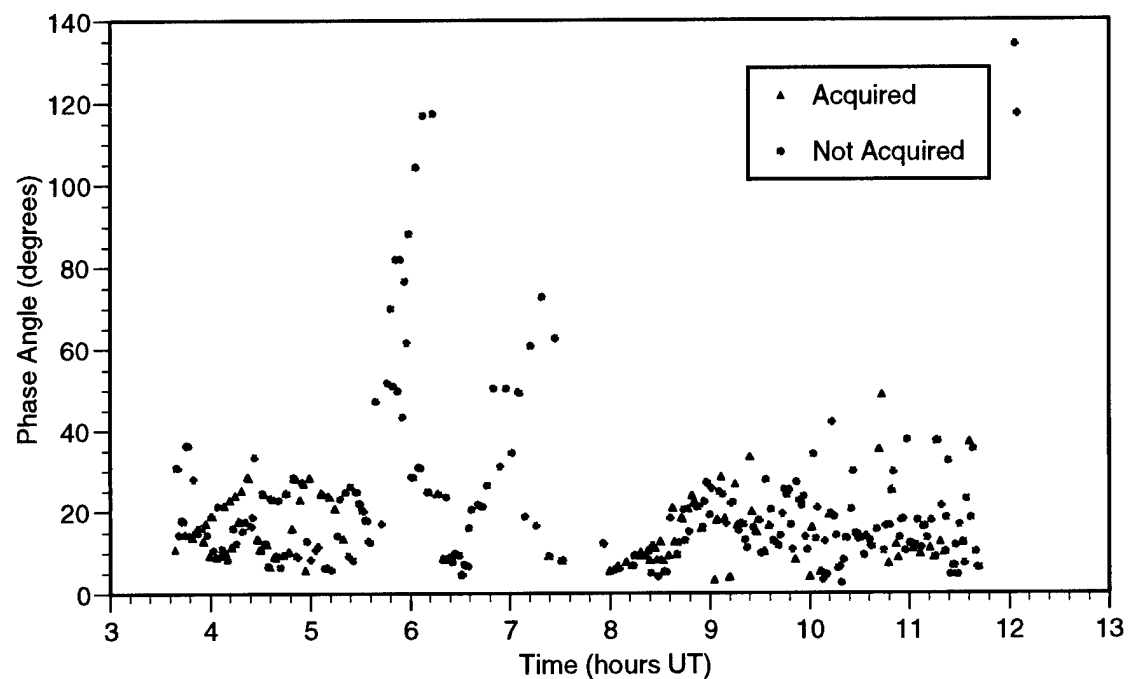


Figure 60 Satellite Phase Angles for Day 225 (13 Aug 98 UT)

P. Day 226 (14 Aug 98 UT)

Operating Environment

Weather: Red/yellow weather detected 04 and 07 UT with some yellow condition through the remainder of the night.
 AWPS detected rain between 0317 and 0327 UT.

Lunar Background: Moon max elevation: 49° Illumination: 54%

Hardware Condition: Normal

Day 226 shows an example of SOA operating under yellow and red weather conditions. AWPS sense adverse local conditions, such as rain and high wind conditions, but not high cirrus/cumulus clouds. Although SOA was operational due to local weather conditions, the catalog star match percentage in Figure 73 shows the presence of thick high clouds that resulted in a miscode of 'W' for the first half of the night between 0400 UT and 0800 UT. The second half of the night, between 0800 and 1030 UT, resulted in a high number of 'N' miscodes due to yellow weather conditions.

Legend	
Hrs	:Time duration for statistics in hours
W	:Observations in red weather condition
N	:Not acquired
Acq	:Full acquisition (5 or more obs)
Att/hr	:# Att / Total observation time
#Att	:Total attempts excluding red weather
U	:Image header coordinate error
P	:Partial acquisition (<5 marks)
AddAcq	:Additional objects in tasked FOV

Day	Hrs	#Att	W	U	N	P	Acq	Add Acq	Att/hr
226	0.9	10	20	6	4	0	0	0	N/A
226	1	17	14	8	4	2	3	1	N/A
226	1	6	24	4	2	0	0	0	N/A
226	0.9	9	19	0	3	1	5	4	N/A
226	1	24	4	3	11	2	7	3	N/A
226	1	31	0	3	13	2	12	0	N/A
226	0.3	12	0	1	8	0	3	0	N/A
Total	6.1	109	81	25	45	7	30	8	18

Table 16 Observation summary for Day 226 (14 Aug 98 UT)

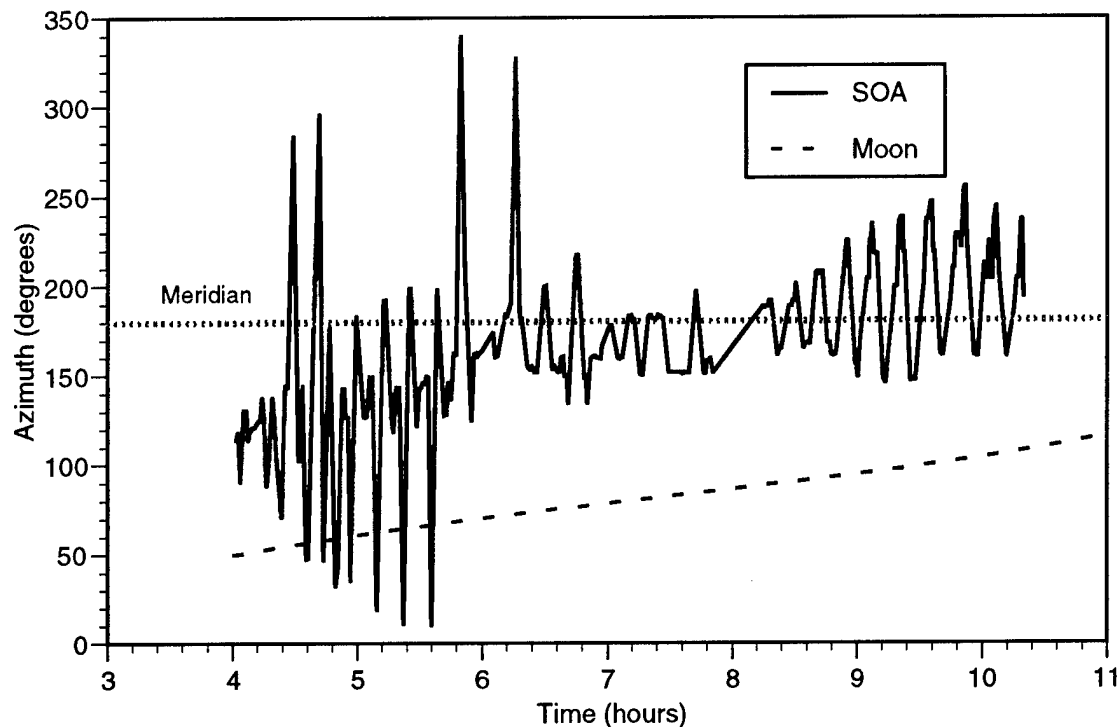


Figure 61 Azimuth Positions for Day 226 (14 Aug 98 UT)

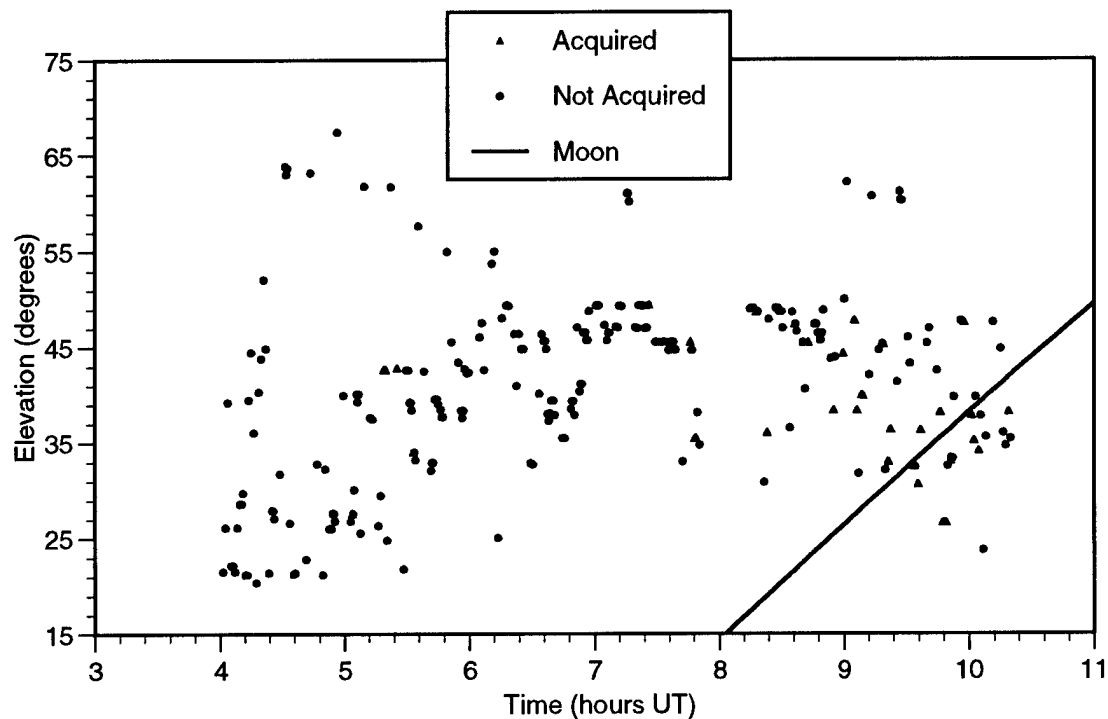


Figure 62 Elevation Positions for Day 226 (14 Aug 98 UT)

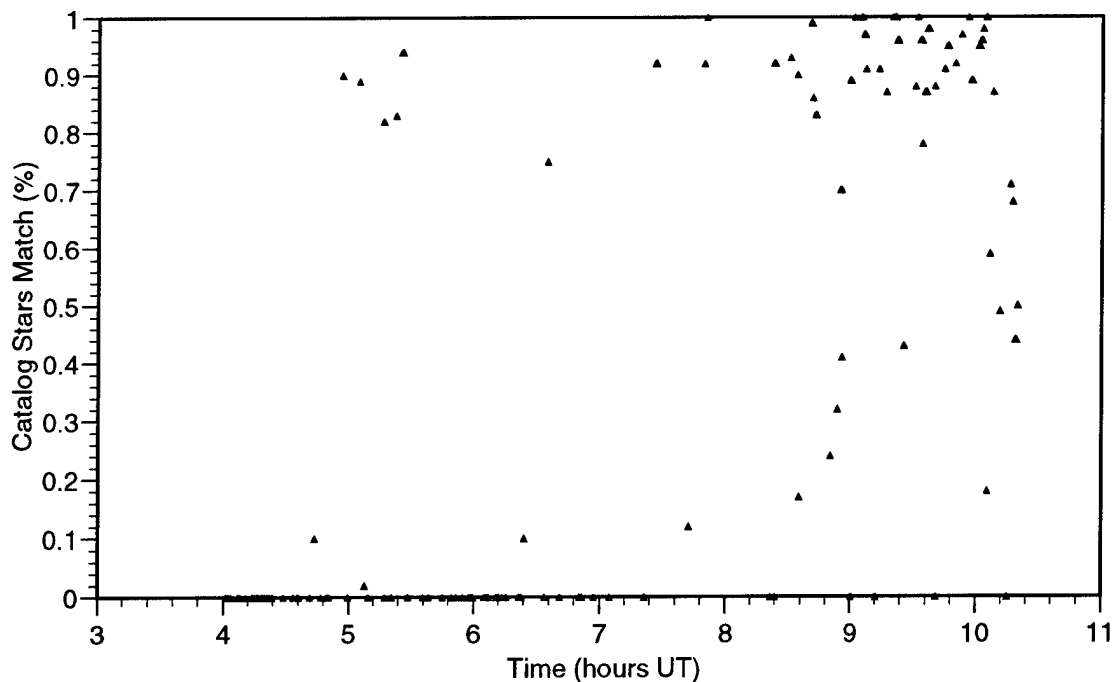


Figure 63 Catalog Star Match Percentage for Day 226 (14 Aug 98 UT)

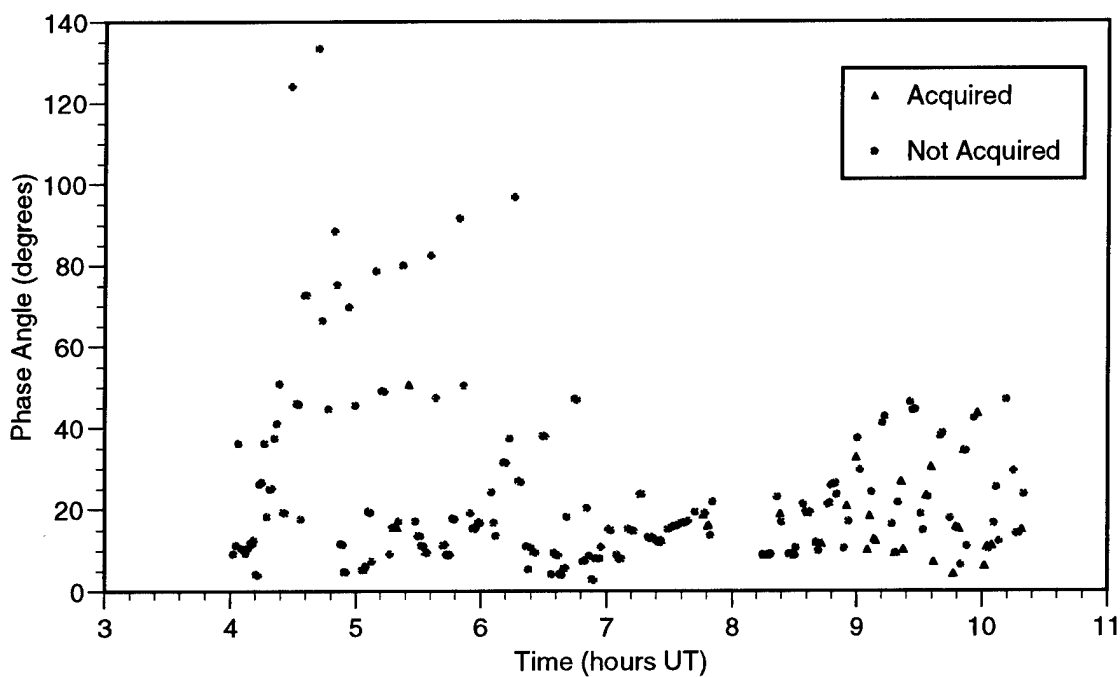


Figure 64 Satellite Phase Angles for Day 226 (14 Aug 98 UT)